BULLETIN

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT

HARVARD COLLEGE, IN CAMBRIDGE.

VOL. XXIII.

CAMBRIDGE, MASS., U. S. A.
1892–93.

Reprinted with the permission of the original publisher
KRAUS REPRINT CORPORATION
New York
1967

SHOUT
SHARE
IT

Printed in U.S.A.

CONTENTS.

PAGE

No. 1. — Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, etc., by the U. S. Fish Commission Steamer "Albatross." II. General Sketch of the Expedition of the "Albatross," from February to May, 1891. By A. AGASSIZ. (22 Plates.) February, 1892 1

No. 2. — Contributions from the Zoölogical Laboratory. XXXI. The Mesoderm in Teleosts: especially its Share in the Formation of the Pectoral Fin. By E. R. BOYER. (8 Plates.) April, 1892 91

No. 3. — Contributions from the Zoölogical Laboratory. XXXII. On Nectonema agile, Verrill. By H. B. WARD. (8 Plates.) June, 1892 135

No. 4. — Studies from the Newport Marine Laboratory. XXIX. Preliminary Note on some Modifications of the Chromatophores of Fishes and Crustaceans. By A. AGASSIZ. (1 Plate.) December, 1892 189

No. 5. — Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, etc., by the U. S. Fish Commission Steamer "Albatross." III. On a Peculiar Type of Arenaceous Foraminifer from the American Tropical Pacific, Neusina Agassizi. By A. GOËS. (1 Plate.) December, 1892 195

No. 6. — Reports on the Results of Dredging by the United States Coast Survey Steamer "Blake." XXXIV. Report on the Mollusca dredged by the "Blake," in 1880, including Descriptions of several New Species. By KATHARINE JEANNETTE BUSH. (2 Plates.) January, 1893 199

No. 1. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in Charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross,"* LIEUT. COMMANDER Z. L. TANNER, U. S. N., *Commanding.*

II.*

General Sketch of the Expedition of the "Albatross," from February to May, 1891. By ALEXANDER AGASSIZ.

[Published by Permission of MARSHALL McDONALD, U. S. Fish Commissioner.]

ROUTE OF THE EXPEDITION.

WE left Panama on the 22d of February, and returned there after an absence of twenty days. During our first trip, the route extended from Panama to Point Mala, and next to Cocos Island ; from there we ran in a southerly direction, then northwesterly to Malpelo Island, and back to the hundred fathom line off the Bay of Panama, where we spent several days trawling off the continental plateau of the Bay.

After coaling, we left Panama, and reached Galera Point, where we began our second line, across the Humbolt Current to the southern face of the Galapagos. We spent a few days at the Galapagos visiting Chatham, Charles, Duncan, and James Islands, and then steamed for Acapulco, making casts of the trawl, and of the surface and the submarine townets, at various points.

After a few days' delay at Acapulco to coal the ship, we left that port on the 15th of April for our third cruise, into the Gulf of California, and steamed as far as Cape Corrientes without attempting to do any trawling. The character of the bottom, as indicated on the charts, promised nothing different from what we had dredged off Acapulco, and on the line from there to the Galapagos Islands. We made one haul off Cape

* I. Calamocrinus Diomedæ, a new Stalked Crinoid. Memoirs Mus. Comp. Zoöl., Vol. XVII. No. 2, 1892. 96 pp. With 32 plates.

Corrientes, bringing up nothing but mud and decomposed vegetable matter. This induced us to keep up the Gulf of California, till we were off the Tres Marias. From that point until we reached Guaymas, on the 23d of April, we carried on our usual operations with the trawl, the tow-net, and the Tanner net.

In the afternoon of the same day I parted from the ship with great regret, but more than satisfied with the results of this expedition.

The more I saw of the "Albatross," the more I became convinced that her true field is that of exploration. She is a remarkably fine sea boat, and has ample accommodation for a staff of working specialists such as would be needed on a distant expedition. The time will soon come when the Fish Commission will hardly care to continue to run her, and I can conceive of no better use for so fine a vessel than to explore a belt of 20° of latitude north and south of the equator in the Pacific, from the west coast of Central America to the East Indian Archipelago.

The success of the "Albatross" thus far has depended entirely upon the zeal, energy, intelligence, forethought, and devotion of Captain Tanner, if I may judge of the past by the present. He never spares himself, and he is always ready to make the most of the time at his disposal for the benefit of the special object he has in charge. He looks after every haul of the trawl himself, and will not allow any one else to jeopard in any way the material of the vessel, or the time it requires to make a haul. That responsibility he assumes himself, and it constitutes his daily work. In looking over the records of the "Albatross" during her voyage from New York to San Francisco, I am struck with the amount of work which has been accomplished. It would be but a just return to Captain Tanner, if Congress would make the necessary appropriations to work up and publish, not only all that he has brought together on that cruise, but also what has been left untouched thus far of the immense collections made from the time he first commanded the "Albatross." In his cruises off the east coast of the United States and in the Caribbean, to say nothing of his explorations in the Gulf of California, on the coast of California, on the coast of Alaska, and in the Bering Sea, he has accumulated in the "Albatross" endless most interesting material, which no other ship could have got together unless she had another Tanner in command.

My cordial thanks are due to Colonel Marshall McDonald, the United States Fish Commissioner, for having given me the opportunity to join the "Albatross" on this extended cruise, and for his kindness in urging the President to allow the vessel to be detailed for this work. To Mr.

Richard Rathbun, of the United States Fish Commission, I must also express my thanks for the care, interest, and patience with which he attended to the endless details connected with the fitting out of the "Albatross" for her voyage. Since the arrival of the collections at Washington, he has taken full charge of their care and distribution to the specialists who will write reports on the results of the expedition.

I can hardly express my satisfaction at having had the opportunity to carry on this deep-sea work on the "Albatross." While of course I knew in a general way the great facilities the ship afforded, I did not fully realize the capacity of the equipment until I came to make use of it myself. I could not but contrast the luxurious and thoroughly convenient appointments of the laboratory of the "Albatross" for work by day and by night with my previous experiences. The constant assistance of Messrs. C. H. Townsend and N. B. Miller in the care of the specimens was most welcome, giving me ample time to examine the specimens during the process of assorting them, and to make such notes as I could between successive hauls, while paying some attention also to the work of the artist, Mr. Magnus Westergren. He found his time fully occupied, and we have in this trip brought together a considerable number of colored drawings, giving an excellent general idea of the appearance of the inhabitants of the deep waters as they first come up. These drawings can be used to great advantage with the specimens in making the final illustrations intended to accompany the reports of the specialists who have kindly undertaken the task of working up the different groups.

Stations occupied by the "Albatross," February to May, 1891.

During this cruise of the "Albatross," we occupied in all eighty-four Stations where the trawl, tangles, and tow-nets were used, and in addition five Stations at which the surface and submarine tow-nets alone were in use. Forty-four Stations, Nos. 3353 to 3397, with three tow-net Stations, were occupied on our first trip. Stations Nos. 3398 to 3423, as well as three others, were occupied during our second trip, from Panama to Acapulco via the Galapagos, and in the Gulf of California we occupied Stations Nos. 3424 to 3437, and three tow-net Stations.

The following record gives the work done at each Station: —

RECORD OF SUBMARINE TOW-NET STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."*

MARCH AND APRIL, 1891.

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	Depth at which towed, in Fathoms.	Time in Minutes.	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°					
3282 Dr.	March 7	8 50 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200	15	
"	" 7	9 53 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200		Hauled up straight from 200 fathoms in 10 minutes; from 100 fathoms, in about 5 minutes. About 60 miles from the 100 fathom line.
"	" 7	10 23 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	100		
3388 Dr.	" 9	10 31 A.M.	7 6 0	79 48 0	73	36.2	1168	gn. glob. Oz.	400	17	Young Eryoneicus in upper part of net. 15 miles from 100 f. line, and 25 miles from nearest land.
2619 Hyd.	" 11	8 25 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	300	19	
"	" 11	9 44 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	1000 to 1482 †	16	Drifted into 1482 f. Atolla in upper part of net.
2627 Hyd.	" 25	6 49 A.M.	0 36 0 *South.*	82 45 0	81	36.0	1832	gy. glob. Oz.	1770 to 1739 †	20	
2628 Hyd.	" 26	9 14 A.M.	0 13 0 *North.*	84 52 0	81	—	—	——	204	20	Towed awhile from 200 f. to surface, to fill upper part of net. About 250 m. from the Galapagos.
3414 Dr.	April 8	6 57 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	100	20	350 miles from land.
"	" 8	7 47 A.M.	10 14 0	96 28 0	82	35 8	2232	gn. M.	200	10	
"	" 8	8 49 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	20	
"	" 8	10 30 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	15	
——	" 9	10 4 A.M.	12 34 0	97 21 0	82	—	—	——	175	8	About 300 miles S. E. of Acapulco. Depth.‡
——	" 9	8 3 P.M	13 33 30	97 57 30	83	—	—	——	175	10	About 250 miles S. E. of Acapulco. Depth.‡
——	" 11	8 45 A M.	16 32 0	99 42 0	80	—	—	——	300	20	About 30 miles S E. of Acapulco. Depth.§
——	" 16	10 10 A.M.	17 39 30	102 11 30	76	—	—	——	175	15	About 120 m. N. W. of Acapulco. Depth over 2,000 f.
3436 Dr.	" 22	1 22 P.M.	27 3 40	110 53 40	72	37.2	905	bn. M. bk. Sp.	800	15	Surface about 75 miles S. W. of Guaymas, half-way across Gulf of California. New Bougainvillia, Periphylla.
2637 Hyd.	" 22	7 21 P.M	27 20 0	110 54 0	71	38.0	773	bn. M. bk. Sp.	700	15	About 50 miles S. W. of Guaymas. Nettastoma.
3437 Dr.	" 23	5 31 A.M.	27 39 40	111 0 30	70	40.0	628	bn. M. bk. Sp.	600	15	Shoaled water and dragged on bottom.
2638 Hyd.	" 23	7 26 A.M.	27 38 0	111 4 0	72	39.2	622	bn. M. bk. Sp.	500 to 570 †	15	

* Tanner tow-net at all Stations except Station 3282, March 7.
† Depth varying between these points.
‡ Between two Stations, over 2,000 fathoms.
§ Between two Stations, about 500 fathoms.

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
	Feb. 22	8 0 P.M.	—	—	—	—	—	—	Surface tow-net.
3353	Feb. 23	8 56 A.M.	7 6 15	80 34 0	73	39.0	695	gn. M.	
3354	" 23	1 25 P.M.	7 9 45	80 50 0	78	46.0	322	gn. M.	
3355	" 23	3 1 P.M.	7 12 20	80 55 0	81	54.1	182	bk. G. Sh.	
3356	" 23	7 30 P.M.	7 9 30	81 8 30	83	40.1	546	sft. bl. M.	Surface tow-net. 15 miles from Mariato Point.
3357	" 24	6 17 A.M.	6 35 0	81 44 0	83	38.5	782	Modern Greensand.	Surface tow-net.
3358	" 24	11 38 A.M.	6 30 0	81 44 0	83	40.2	555	Mod rn Greensand.	
3359	" 24	2 4 P.M.	6 22 20	81 52 0	83	42.0	465	Rky.	
3360	" 24	5 20 P.M.	6 17 0	82 5 0	83	36.4	1672	fne. bk. dk. gn. S.	Surface tow-net.
3361	" 25	7 33 A.M.	6 10 0	83 6 0	82	36.6	1471	gn. Oz.	
3362	" 26	7 20 A.M.	5 56 0	85 10 30	84	36.8	1175	gn. M. S. rky.	Intermediate net of Chun and Peterson.
3363	" 26	4 37 P.M.	5 43 0	85 50 0	83	37.5	978	wh. glob. Oz.	Surface tow-net.
3364	" 27	6 58 A.M.	5 30 0	86 8 30	81	38.0	902	yl. glob. Oz.	
3365	" 27	1 30 P.M.	5 31 0	86 31 0	85	37.0	1010	yl. glob. Oz.	Surface tow-net.
3366	" 27	8 4 P.M.	5 30 0	86 45 0	84	37.0	1067	yl. glob. Oz.	
3367	" 28	6 38 A.M.	5 31 30	86 52 30	82	57.1	100	Rky.	
3368	" 28	7 21 A.M.	5 32 45	86 54 30	82	58.4	66	Rky.	Surface tow-net.
3369	" 28	8 7 A.M.	5 32 45	86 55 20	82	62.2	52	Nullipore or rky.	
3370	" 28	10 3 A.M.	5 36 40	86 56 50	84	54.8	134	Rks. & S.	At Cocos Island. Surface tow-net at night.
3371	March 1	7 49 A.M.	5 26 20	86 55 0	82	39.0	770	glob. Oz.	
3372	" 1	5 51 P.M.	4 49 0	86 11 20	84	38.8	761	gy. glob. Oz.	8 P. M. Surface tow-net.
3373	" 2	10 33 A.M.	4 2 0	84 58 0	82	36.6	1877	br. M. bk. sp.	
3374	" 3	10 35 A.M.	2 35 0	83 53 0	80	36.4	1823	gn. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."— *Continued.*

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3375	March 4	6 36 A.M.	2 34 0	82 29 0	77	36.6	1201	gy. glob. Oz.	Surface tow-net. In trawl swimming Holothurian, Periphylla, Atolla, and Eryoneicus.
3376	" 4	4 27 P.M.	3 9 0	82 8 0	78	36.3	1132	gy. glob. Oz.	
3377	" 5	8 38 A.M.	3 56 0	81 40 15	77	38.0	764	M.	
3378	" 5	11 45 A.M.	3 58 20	81 36 0	78	55.9	112	brk. sh.	
3379	" 5	2 15 P.M.	3 59 40	81 35 0	78	—	52	Rks.	
3380	" 5	4 51 P.M.	4 3 0	81 31 0	79	37.2	899	Rks.	In trawl, Periphylla, Atolla.
3381	" 6	8 38 A.M.	4 56 0	80 52 30	77	35.8	1772	gn. M.	Siphonophore clinging to wire rope.
3382	" 7	10 46 A.M	6 21 0	80 41 0	75	35.8	1793	gn. M.	Submarine tow-net. 8:30 P. M., Surface tow-net.
3383	" 8	6 51 A.M.	7 21 0	79 2 0	74	36.0	1832	gr. glob. Oz.	Atolla in trawl, Periphylla, Nauphanta, fragments of Drymonema.
3384	" 8	1 20 P.M.	7 31 30	79 14 0	74	42 0	458	gn. S.	Stomobrachium in trawl.
3385	" 8	3 7 P.M.	7 32 36	79 16 0	72	45.9	286	gn. M.	
3386	" 8	4 54 P.M.	7 33 12	79 17 15	73	48.0	242	fne. gy. S.	
3387	" 8	7 21 P.M.	7 40 0	79 17 50	74	56.4	127	fne. gy. S.	Surface tow-net.
3388	" 9	6 41 A.M.	7 6 0	79 48 0	73	36 2	1168	gn. glob. Oz.	Submarine tow-net. In trawl, Stomobrachium. In tow-net, open part, Periphylla.
3389	" 9	2 10 P.M.	7 16 45	79 56 30	74	48.8	210	gn. M.	
3390	" 9	4 25 P.M.	7 26 10	79 53 50	74	62.6	56	fne. gy. S. G.	
3391	" 9	7 15 P.M.	7 33 40	79 43 20	73	55.8	153	gn. M.	
3392	" 10	6 30 A.M.	7 5 30	79 40 0	73	36.4	1270	hard.	Rhabdamina bottom.
3393	" 10	1 21 P.M.	7 15 0	79 36 0	74	36.8	1020	gn. M.	
3394	" 10	5 43 P.M.	7 21 0	79 35 0	73	41.8	511	dk. gn. M.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS. — *Continued.*

Serial Number.	DATE.	TIME.	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3395	March 11	2 20 P.M.	7 30 36	78 39 0	70	38.5	730	Rky.	
3396	" 11	5 15 P.M.	7 32 0	78 36 30	70	47.4	259	hrd. gy. M. S.	
3397	" 11	6 32 P.M.	7 33 0	78 34 20	71	57.3	85	stf. gn. M. brk.	Surface tow-net.
3398	" 23	3 16 P.M.	1 7 0	80 21 0	84	36.0	1573	gn. Oz.	Surface tow-net, off Galera Point.
3399	" 24	6 37 A.M.	1 7 0	81 4 0	80	36.0	1740	gn. Oz.	Siphonophore on wire. Phæodaria fragments. Surface tow-net.
			South.						
3400	" 27	6 10 A.M.	0 36 0	86 46 0	81	36.0	1322	lt. gy. glob. Oz.	Surface tow-net, March 25, pelagic Holothurian.
3401	" 28	4 45 A.M.	0 59 0	88 58 30	82	44.0	395	glob. Oz.	
3402	" 28	7 13 A.M.	0 57 30	89 3 30	82	42.3	421	R. glob. Oz.	
3403	" 28	10 19 A.M.	0 58 30	89 17 0	82	43.3	384	fne. gy. S. bk. Sp.	
3404	" 28	1 16 P.M.	1 3 0	89 28 0	83	43.2	385	R.	Tangles.
3405	" 28	3 42 P.M	0 57 0	89 38 0	83	60.0	53	P. Co. Sh.	
3406	April 3	6 47 A.M.	0 16 0	90 21 30	81	41.3	551	R.	
3407	" 3	10 48 A.M.	0 4 0	90 24 30	81	37.2	885	glob. Oz.	Tangles.
			North.						
3408	" 3	4 7 P.M.	0 12 30	90 32 30	83	39.5	684	glob. Oz.	Tangles.
3409	" 3	7 24 P.M.	0 18 40	90 34 0	82	42.3	327	bk. S.	Tangles. Surface tow-net. Off Bindloe Island, 4 miles west.
3410	" 3	8 48 P.M	0 19 0	90 34 0	82	44.2	331	bk. S.	
3411	" 4	7 35 A.M.	0 54 0	91 9 0	82	36.2	1189	yl. glob. Oz.	
3412	" 4	6 11 P.M	1 23 0	91 43 0	82	38.0	918	R.	9 P. M., surface tow-net, 5 m. off Wenman Islands.
3413	" 5	8 34 A.M.	2 34 0	92 6 0	82	36.0	1360	glob. Oz. dk. Sp.	At noon, surface tow-net.
3414	" 8	11 14 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	Submarine tow-net and surface tow-net.
3415	" 10	9 39 A.M.	14 46 0	98 40 0	82	36.0	1879	br. M. glob. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS." — *Continued.*

Serial Number.	DATE.	TIME	POSITION. Latitude North.	POSITION. Longitude West.	TEMPERATURES. Surface.	TEMPERATURES. Bottom.	Depth in Fathoms.	Character of Bottom.	REMARKS.
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
3416	April 11	9 46 A.M.	16 32 30	99 42 40	81	40 5	419	fne. br. M.	
3417	" 11	11 44 A.M.	16 32 0	99 48 0	82	40.6	493	gn. M.	
3418	" 11	2 57 A.M.	16 33 0	99 52 30	82	39.0	660	br. S. bk. Sp.	
3419	" 11	5 59 P.M.	16 34 30	100 3 0	81	39.0	772	gn. M. bk. Sp.	Surface tow-net.
3420	" 12	7 48 A.M.	16 46 0	100 8 20	82	39.6	664	dk. gn. M.	
3421	" 12	11 32 A.M.	16 47 20	100 0 10	82	42.9	388	dk. gn. M.	
3422	" 12	12 35 P.M.	16 47 30	99 59 30	83	53.5	141	gn. M.	
3423	" 12	1 31 P.M.	16 47 30	99 59 20	83	56.0	94	gn. M.	
3424	" 18	11 18 A.M.	21 15 0	106 23 0	76	38.0	676	gy. S. bk. Sp. Glob.	
3425	" 18	2 14 P.M.	21 19 0	106 24 0	76	39.0	680	gn. M. & S.	
3426	" 18	3 45 P.M.	21 21 0	106 25 0	76	51.2	146	Rky.	
3427	" 18	4 3 P.M.	21 22 15	106 25 0	75	51.2	80	Rky.	
3428	" 18	6 40 P.M.	21 36 30	106 25 0	76	48.1	238	dk. gy. S. Glob.	
3429	" 19	5 39 A.M.	22 30 30	107 1 0	73	37.0	919	gn. M. Glob. Oz.	
3430	" 19	3 27 P.M.	23 16 0	107 31 0	73	37.9	852	bk. S.	
3431	" 20	6 33 A.M.	23 59 0	108 40 0	70	37.0	995	lt. bro. M. Glob.	
3432	" 20	2 38 P.M.	24 22 30	109 3 20	70	37.8	1421	br. M. bk. Sp.	
3433	" 21	6 31 A.M.	25 26 15	109 48 0	69	36.5	1218	br. M. bk. Sp.	
3434	" 21	10 14 A.M.	25 29 30	109 48 0	70	36.4	1588	br. M. bk. Sp.	Surface tow-net.
3435	" 22	8 56 A.M.	26 48 0	110 45 20	70	37.3	859	br. M. bk. Sp.	
3436	" 22	3 10 P.M.	27 34 0	110 53 40	72	37.2	905	br. M. bk. Sp.	Submarine tow-net and surface tow-net.
3437	" 23	5 4 A.M.			70	40.0	628	br. M. bk. Sp.	Submarine tow-net dragged on the bottom. About 50 miles south of Guaymas.

Topography of the Bottom in the Panamic Region.

There can be no more striking contrast than exists between the topography of the two sides of Central America. The Atlantic side[1] with the great inland seas of the Gulf of Mexico and Caribbean, and the great submarine banks extending from Yucatan, Honduras, and Venezuela, while on the Pacific side (Plate III.) the continental slope is steep, the 2,000 fathom line often coming within 100 miles of the coast line. (See Plates V. to IX.) The 100 fathom line, with the exception of the stretch forming the Bay of Panama, and a comparatively narrow continental shelf along a part of the shore from Costa Rica to Tehuantepec, is within a few miles of the shore as far as the southern entrance of the Gulf of California, where it broadens out again to take in the Tres Marias group of islands. The 500 and 1,000 fathom lines are parallel with the 100 fathom line, forming a very abrupt slope from Ecuador to the Gulf of California, except along the stretch between Cape Mala and Tehuantepec, where the distance between those curves is somewhat greater (Plate III.), but still so slight as not to alter materially the prevailing steepness of the continental slope. In this same stretch the 1,500 fathom line is from three to four times as distant from the 1,000 fathom curve as it is off the coast line extending from Panama to Ecuador, and from Tehuantepec to Cape Corrientes; at the mouth of the Gulf of California, the 1,500 fathom line extends across the opening of the Gulf of California, coming in again close to Cape San Lucas.

The rise upon which Malpelo (Plate VI.) is situated is bounded by the 1,500 fathom line (Plate III.), and separated by a channel with over 1,700 fathoms of water from the Columbian and Ecuadorian coasts. And again the same curve forms a gigantic comma-shaped figure, taking in Cocos Island (Plates III. and V.) and the Galapagos group; it is separated from the 1,500 fathom line off Mariato Point by over 1,600 fathoms, and from the Malpelo Bank and Ecuadorian coast by over 1,800 fathoms. (See Plate III.) The course of the 2,000 fathom line shows how very uniform is the depth of the floor of the Pacific beyond the 1,500 fathom curve. The rise to the Galapagos is most gradual close to the islands, and the different islands of the Revilla Gigedo group, varying in distance from 300 to 500 miles from Cape San Lucas, form steep peaks suddenly rising from a comparatively level oceanic floor of an average depth of about 2,000 fathoms (see Plate III.), which is nearly the

[1] See Figs. 55–59, Three Cruises of the "Blake."

general depth between them and the mainland. This flat floor also extends farther to the southeast towards the 1,500 fathom line from which the Galapagos rise begins, and in the direction of the Costa Rica coast. The slope from the 1,000 fathom line to the 1,500 and 2,000 fathom line is much more gradual between Costa Rica and Tehuantepec than farther north along the coast of Mexico as far as the Gulf of California (Plate III.).

Our knowledge of the hydrography of the Galapagos is still quite incomplete. (See Plates IV. and VIII. to XII.) There are unfortunately no soundings between James and Albemarle, or between Indefatigable and Albemarle, to indicate the probable depth of the ridges connecting them.

Nothing likewise is known of the depth of the channels between Abingdon and Bindloe and Tower, and no soundings exist to show how far to the westward the deep valley (of over 800 fathoms) separating Bindloe from Indefatigable extends (Plate X. Fig. 2), as there are no soundings between either Bindloe or Abingdon and Albemarle. There seems little doubt that the northernmost islands, the isolated rocks of Culpepper and Wenman, are themselves separated by comparatively deep water (Plate XII. Figs. 1, 2), and in turn separated from the northeastern group of islands, Abingdon, Bindloe, and Tower, by a tongue of the ocean of at least 1,000 fathoms in depth, and from sixty to seventy miles in width. From a careful examination of the soundings thus far made, it seems probable that the 100 fathom line connects Indefatigable, Duncan, Barrington, and Charles, (see Plate IV., as well as the line between Charles and Indefatigable, Plate XI. Fig. 1,) and that there is also a connecting ridge inside that same depth between those islands and Albemarle to the southeast of Cape Woodford on Albemarle, or a wider plateau of which Duncan Island is one of the culminating summits.

A comparatively shallow connection may also exist between Cape Nepean on James Island and Albemarle in the direction of Cowley Island, Narborough itself being only separated from Albemarle by a channel less than 75 fathoms in depth (Plate IV.). The soundings between Chatham, Barrington, and Hood are so few in number that we are not yet able to decide whether these southeastern islands, Chatham and Hood (Plate XI. Figs. 2, 3), are not perhaps connected by a ridge connecting Hood and Macgowen Reef (Plate IV.), and also uniting them with the great plateau which the islands of Barrington, Charles, Indefatigable, Duncan, Albemarle, Narborough, and perhaps James, have gradually built up. But it may be that the tongue of deeper water

extending between Hood and Chatham (287 fathoms) runs towards Barrington, and also separates that island from Chatham (Plate XI. Fig. 2).

On account of the small number of soundings, no attempt has been made to draw curves of depth on the chart of the Galapagos (Plate IV.).

The structure of Albemarle, made up of a series of at least five volcanic centres, with the adjacent Narborough, gives us an indication of the probable appearance of the central and western group of islands were they still active so as finally to become connected and form a huge island, with James, Indefatigable, Jarvis, Duncan, Barrington, and Charles as the culminating points of the plateau formed by the 100 fathom line. We may therefore look upon the Galapagos Islands as a group of volcanic islands, gradually built up by successive flows of lava upon a huge mound, itself perhaps raised by the same agencies from the floor of the ocean; more active local flows in the same region having at special points built up more rapidly the northern group of islands, Wenman and Culpepper, and the two other groups of islands we have recognized.

Character of the Bottom Deposits.

We dredged frequently in most characteristic Globigerina ooze. On one occasion the trawl came up literally filled with masses of a species of Rhabdamina closely allied to R. lineata.

It is interesting to note that, at two localities not far from the coast off Mariato Point, we came across patches of modern greensand similar in formation to the patches discovered off the east coast of the United States by the earlier dredgings of the Coast Survey, of Pourtalès, and of the "Blake." (See page 5, Stations 3357, 3358.)

Nearly everywhere along our second line of exploration, except on the face of the Galapagos slope, we trawled upon a bottom either muddy or composed of Globigerina ooze, more or less contaminated with terrigenous deposits, and frequently covered with a great amount of decayed vegetable matter. We scarcely made a single haul of the trawl which did not bring up a considerable amount of decayed vegetable matter, and frequently logs, branches, twigs, seeds, leaves, fruits, much as during our first cruise.

I was struck, while trawling on our second line between the Galapagos and Acapulco, to observe the great distance from shore to which true terrigenous deposits were carried. There was not a station there occupied of which the bottom could be characterized as strictly oceanic.

At our most distant points from shore, the bottom specimens invariably showed some trace of admixture of terrigenous material. A very fine mud was the characteristic bottom we brought up, often very sticky, and enough of it usually remained in the trawl, even when coming up from depths of over 2,000 fathoms, materially to interfere with the assorting of the specimens contained in our hauls. This mud continued all the way from the Galapagos to Acapulco, and up to the mouth of the Gulf of California, where it became still more of an impediment to dredging, so that little work was done until we passed the Tres Marias. Even then the trawl was ordinarily well filled with mud, and with it came up the usual supply of logs, branches, twigs, and decayed vegetable matter.

On going farther north, into the Gulf of California, the nature of the bottom did not change materially from what it had been along the coast from Acapulco to Cape Corrientes; it was the same viscid mud, mixed occasionally with Globigerinæ and masses of vegetable matter. So we found the trawling most difficult from the weight of the mud brought up, but occasionally a haul was made which more than repaid us for the time spent on the less productive ones.

In the dredgings of the "Blake" in the Gulf of Mexico, off the West Indies, and in the Caribbean, my attention had already been called to the immense amount of vegetable matter dredged up from a depth of over 1,500 fathoms on the lee side of the West India Islands. But in none of the dredgings we made on the Atlantic side of the Isthmus did we come upon such masses of decomposed vegetable matter as we found on this expedition. There was hardly a haul taken which did not supply a large quantity of water-logged wood, and more or less fresh twigs, leaves, seeds, and fruits, in all possible stages of decomposition.

Temperature Sections in the Panamic District.

The temperature sections taken by the "Albatross" during this cruise give us a fair sketch of the temperature of the currents running north parallel with the Mexican coast, of the counter current running towards the Gulf of Panama, of a branch of the Humboldt Current running from the coast of Peru and deflected by the Galapagos to the northward, the main branch of the current running south of the Galapagos and forming a great westerly current running nearly at right angles from the coast of Central America past the Galapagos, and becoming the Equatorial Current of the Pacific.[1]

[1] The Peruvian stream, the bulk of which flows westerly south of the Galapa-

A transverse section of the Mexican Current from Mariato Point to Cocos Island (Plate V.) shows the water to be considerably warmer near the mainland than about half-way across to Cocos Island. At the 1,000 fathom line, the 60° curve is found at a depth of more than 100 fathoms, while at Station 3361, at a depth of 1,471 fathoms, nearly the half-way point, the 60° curve has risen to a depth of 50 fathoms from the surface, to sink to 75 fathoms and rise to 25 fathoms again at Station 3362 at a depth of 1,175 fathoms, and at Station 3364 in 902 fathoms, towards Cocos Island, the surface belt becoming again decidedly warmer near the island. The curve of 45° temperature corresponds nearly with the 300 fathom line, rising near the mainland and falling somewhat at Cocos Island. The 40° curve in its turn corresponds practically with the 600 fathom line except near the mainland, where there seems to have been a colder body of water.

The bottom temperature of 36°.4 between 1,600 and 1,700 fathoms shows a free connection with the oceanic floor, and the temperatures on the ridges indicated by the soundings, the one near the mainland (42°), the other near Cocos Island (38°), show that they are not parts of an oceanic barrier, but are probably short ridges parallel with the mainland and the general trend of Cocos Island.

A temperature section run across the westerly Panamic current in a southeasterly direction from Cocos Island (Plate VI. Fig. 1) shows remarkably uniform temperature curves of 60°, 45°, and 40°. The 60° curve, after leaving the shores of Cocos Island, rises to about the 45 fathom line, the water as we go south gradually becoming warmer, and at Station 3375, about 100 miles southwest of Malpelo, the 60° curve is down to the 75 fathom line. The 45° curve barely rises above the 300 fathom line near Cocos, and at Station 3375 falls somewhat below it. The 40° curve is nearly parallel with the 520 fathom line; so that going south from Cocos Island the body of water above the 500 fathom line is considerably warmer than in the section from Cocos Island to the mainland.

gos, divides off Ecuador, one branch, the westerly, extending to the eastward of the Galapagos, the other flowing into the Bay of Panama. The westerly branch meets the eastern equatorial set, and the eastern branch meets north of the Bay of Panama both the easterly equatorial set and the Mexican branch of the California Current. There is thus found off the Bay of Panama, from the coast of Costa Rica and in a southerly direction, and northerly in the triangle between the Galapagos, Point Mala, and Acapulco, a most complicated system of currents and counter currents. These currents had a marked effect on the ship's course, and frequently set us one day thirty or forty miles east, the next day as many miles in a westerly direction.

In the section from Station 3375 towards Malpelo and to the Pearl Islands in the Bay of Panama (Plate VI. Fig. 2), the water becomes somewhat colder as we approach Malpelo and as far as Station 3,381 in 1,772 fathoms, where the temperature gradually rises again (the 40°, 45°, and 60° curves) towards the Bay of Panama, although the surface temperature has been gradually diminishing from 84° off Cocos Island to 77° off Malpelo, to become as low as 73° off the mouth of the Bay of Panama in 1,168 fathoms, to rise again to 75° in the shallow water of the bay itself.

The three temperature sections of Plate VII. Figs. 1, 2, 3, from Station 3392 to Caracoles Point, on the east shore of the Bay of Panama, and to Point Mala, and from Station 3383, fifty miles to the south of Caracoles Point, to Panama, show an increase of temperature as we rise above the continental slope to the heated waters of the bay, and close to Point Mala on its western face.

In the temperature section from Galera Point to Chatham Island (Plate VIII.) we find the 60° curve but little below the 50 fathom line, showing plainly that it is from the southern current that the cold water comes which occupies the upper strata of the Bay of Panama. The 45° curve rises above the 300 fathom line close to the mainland, to fall nearly 50 fathoms below it on the slope of Chatham Island. The 40° curve is below the 600 fathom line near the mainland, but rises to that line off Galera Point, to fall again nearly to 675 fathoms on the Galapagos slope.

It will be noticed that the upper belt of 50 fathoms varies considerably in temperature, ranging near Galera Point fully 20° in less than 50 fathoms, and in comparatively short distances more than 17°, the surface temperature varying from 80° to 84° on the way to Chatham, and the temperature at the 50 fathom line from 59°.1 to 64°.3.

The bottom temperature is fully half a degree colder below 1,300 fathoms than it is in the sections from Mariato Point to Cocos, and southerly from that island the colder water of the bottom, 36°, extends to the western face of the continental slope off the Bay of Panama as far as Point Mala, as is seen in the sections of Plate VII. Figs. 1 and 2.

The temperature of the upper strata rises somewhat as we approach the Galapagos, the 60° curve being found at a depth of 75 fathoms (Plate VIII.) off Chatham Island.

In the temperature section run in a northwesterly direction from the Galapagos to Acapulco (Plate IX.) we obtained the deepest soundings of

our cruise, the temperature at a depth of 2,232 fathoms, somewhat more than half-way between Culpepper and Acapulco, falling to 35°.8, the temperature being below 36° in the whole of the great basin extending between the northerly slope of the Galapagos and the continental slope off Acapulco. The surface temperature was 83° off Chatham, it fell to 81° off James, and varied between 81° and 83° to fall to 81° again about half-way to Acapulco, to rise to 84° and fall to 80° off Acapulco. The 60° curve rises among some of the Galapagos Islands almost to the 50 fathom line, but falls rapidly below the 100 fathom line between Abingdon and Wenman, retaining that depth nearly to Station 3414 in 2,232 fathoms (Plate IX.), showing the presence of a large mass of warm water flowing eastwardly. From that point it rises rapidly above the 50 fathom line to a short distance off Acapulco, where the water close to the shore becomes warmer again. The 45° curve follows nearly the line of the 60° curve, reaching for a great part of its length the line of 350 fathoms. But the 40° curve shows more markedly than the 45° curve the influence of the warmer body of water moving eastward, and again as markedly that of the colder belt close to the Mexican mainland. It reaches well below the 600 fathom line for more than two thirds its length, extending for a considerable distance to 630, and even to 650 fathoms.

A comparison of the temperature curves of Plates VIII. and IX. will show in the one case the large belt of warmer water flowing east in the greater part of the oceanic basin extending between the Galapagos and Acapulco, and the comparatively colder water flowing north in the oceanic valley extending between Cape San Francisco (Galera Point) and the Galapagos.

The few temperatures taken between the different islands of the Galapagos are interesting as showing the southern islands, Chatham, Hood, and Charles, to be somewhat within the influence of the colder Humboldt Current (Plate XI. Figs. 2, 3, 5), while that which sweeps north of Chatham across the central islands is somewhat warmer (see Plate X. Figs. 1–4), and the upper belt of temperatures is still warmer between Abingdon and Wenman Islands (Plate XII.).

The mixing of the cold and warmer currents flowing between the different islands is plainly indicated by the temperature section from Indefatigable Island to Bindloe (Plate X. Fig. 2), where the 60° curve is at about the 50 fathom line, the 45° at the 300 fathom line, and the 40° curve at the 600 fathom line, while between Abingdon and Wenman the 60° curve is below the 100 fathom line, the

45° curve at about the 350 fathom line, and the 40° curve at the 650 fathom line, indicating a much larger body of warm water between Abingdon and Wenman (Plate XII. Fig. 1) than between Indefatigable and Bindloe, while farther south, near Chatham (Plate XI. Figs. 2, 3, 4), the upper belt of temperatures indicated are the coldest, the 60° curve being above the 50 fathom line.

The temperatures were all taken during February, March, and April of 1891. The sections of the first lines, Panama to Cocos, to Malpelo, and back again to Panama, were taken during the last of February and the beginning of March; those from Galera Point and the Galapagos during the latter part of March and beginning of April; and the line from the Galapagos to Acapulco from the 3d of April to the 12th.

The soundings and temperatures taken during our trip up the Gulf of California indicate free connection with the Pacific, (see the bottom temperatures of Stations 3424 to 3437 in the Gulf of California, page 8, and Hy. 2635, page 17, the deeper stations having practically the same temperature as the oceanic temperatures off Acapulco,) the 1,500 fathom line sweeping across the opening of the gulf with a rapid rise to the 1,000 fathom line running parallel to the two coasts, and a very flat bottom along the central part of the Gulf of California to the line where the 1,000 fathom curve cuts across the gulf off Topolobampo, the bottom rising again gradually along the centre of the gulf to the 500 fathom line, which extends north of Guaymas. The rapid decrease of the surface temperatures as well as that of the upper belt of water to 100 fathoms, within the Gulf of California, is very marked. See the record, on page 8, of Stations 3424 to 3437, and Hy. 2635, page 17.

The accompanying table shows the serial temperatures taken at the different Stations. The position is given in the list of Stations occupied, on pages 4 to 8.

Serial Number.	TEMPERATURE. Of the Air.	At the Surface.	At Fathoms. 25	50	100	200	300	400	500	600	700	800	900	1000	At Bottom.	Depth in Fathoms.
	° F.	°	°	°	°	°	°	°	°	°	°	°	°	°	° F.	
Hy. 2609	79	81	67.2	63.2											57.7	127
Dr. 3356	80	83	68.4	65.9	58.5	52.9	44.9	48.7							40.1	546
" 3357	80	83	74.4			51.8	46.1	43.0	41.0						38.5	782
" 3361	81	82	76.9	59.0	55.0	50.5	46.8	43.6	41.9	40.2	38.3	38.9	37.5	36.5	36.6	1471
" 3362	80	84	71.8		55.8	51 3	46.7				39.1		37.3	36.8	36.8	1175
" 3364	79	81	71.4	58.9	54.4 *	48.8 *	44.9 *	42.8 *	41.0 *						38.0	902
" 3366	83	84	73.7	58.9	55.8	50.9	45.9	44.7	41.5	40.4	38.8				37.0	1067
" 3367	81	82	72.4	69.0											57.1	100
" 3372	85	84	74.4	58.8	55.0	49.1	44.9	42.5	41.0						38.8	761
" 3373	83	82	77.7	60.9	55.9	49.7	44.4	41.9		38.9	38.0	37.5	37.1	37.0	36.6	1877
" 3374	81	80	74 8	61.1	56.6	51.3	45.8	42.3	40.9	39.4					36.4	1823
" 3375	76	77	66.7		58.0	54.2	46 6	43.8	40.9	39.9	38.9	38.0	37.6	37.2	36.6	1201
Hy. 2613	77	77	69.9	59 9	57.7	50.8	45 6	43.3	40.9	39.7	38.8		37.3		36.5	1181
Dr. 3381	78	77	70.9	59.3	55.4	51.5	46.7	42.8	40.5	39.4	38.6	37.7	36.4	36.0	36.0	1772
" 3382	77	75	67.7	61.1	55.3	49.9	45 8	42.8	41.1	39.4	38.8	38.1	36.7	36.3	36.0	1793
" 3383	75	74	63.2	63.4	56.4	49 1	45.0	43.3	41.3	39.6	39.4	39.0	37.4	37.0	36.0	1832
" 3387	77	75	65.8	64.0											56.4	127
" 3388	75	73	64.0	60.9	56.1	49.0	45.5	43.4	43.1	39.8	39.2	38.1	37.7	37.2	36.2	1168
" 3392	76	73	63.0		55.9	49 8	45.0	43.2	40.5	39.7	38.6		37.3	36.8	36.4	1270
Hy. 2619	72	68	65.0	61.8		48.9	45.5	42.6	41.1	40.1	38.7	37.8			36.5	1100
Dr. 3396	77	70	64.5	62.4	55.9										47.4	259
Hy. 2624	77	80		59.1	58.1	56.4	45.6	43.1	41.9	41.0					39 0	724
" 2626	79	80	68.9	60.7											57.5	90
Dr. 3398	84	84	68.8	64 4	59.0	53 8	45.1	42.9	42.0	40.3	39.5	39.0	38.4	37.0	36.0	1573
" 3399	79	80	72.7	65.7	56.1	50 0	44.9	43.0	41 4	40.1	38.9	38.0	37.6	36.7	36.0	1740
Hy. 2627	80	81	71.4	64.3	56.8	49 2	44.8	42.5	41.9	40.2	38.7	38.2	37.7	37.1	36.0	1832
" 2629	85	83	69.9	63.7	56.2	50.1	45.0	42.4	41.8	40.3	39.2	38.6	37.8	36.8	36.0	1488
Dr. 3401	81	82	70.1	63.7	56.6	50.0	46.1								44 0	395
" 3406	79	81	73.5	59.9	57.9	53 9	45.0	42.3							41.3	551
" 3411	79	82	71.8	67.8	61.5	54 0	46.8	43.0	41.3	40.8	39.8	38.9	38.1	37.5	36.2	1189
" 3414	81	82	81.9	72.1	59.5	51.8	47.8	44.4	42.0	40.8	39.6	38 8	38.1	37.8	35.8	2232
" 3415	84	82	77.4	56.8	54.3	49 4	45.3	43.1	41 0	39.5	38 8	37.9	37.0	36.8	36.0	1879
Hy. 2631	79	80	72.5	59.6	54.2	49.5	44.5	42.6	41.1	39.8	38.7	38.2	37.9	37.2	35.8	1823
" 2635	72	74	65.4	59.0	54.6	49.8	44.8	42.2	41.1	39.8	38.7	38.1	37.6	37.0	36.0	2022
Dr. 3435	72	70	65.6	59.2	54.1	49.8		41.8	40.3	39.3	38.5				37.3	859

* These stations are all 50 fathoms deeper than the column in which they are placed.

Specific Gravity of the Ocean in the Panamic District.

During the present cruise of the "Albatross," a few observations of the specific gravity of the water were taken.

On February 23, at a depth of 546 fathoms, the specific gravity was as high as	1.027300
While on the surface it was only	1.025700
On February 24, at the surface, Station 3357	1.024700
" " at 600 fathoms " "	1.026912
" 25, at the surface, Station 3361	1.024712
" " at 1,000 fathoms, " "	1.027512
" 26, at the surface, Station 3362	1.024726
" " at 1,000 fathoms " "	1.027120
" 27, at the surface, Station 3365	1.024900
" " at 900 fathoms " "	1.027100
March 1, at the surface, Station 3371	1.024568
" 7, at the surface, Station 3382	1.026160
Cocos Island, at the surface	1.024600
Off Malpelo " "	1.025960
At the Galapagos, off Chatham, at the surface	1.025726
" " Wreck Bay, " "	1.025926
" " at Charles Island, at the surface	1.026126
" " at Duncan Island, " "	1.026126
" " at Indefatigable Island, at the surface	1.025926
" " off Wenman, at the surface	1.025926
April 6, at the surface	1.026912
" 8, at the surface, Station 3414	1.026112
" 11, off Acapulco, at the surface	1.026712
On the trip of the "Albatross" to these waters from San Francisco, the specific gravity of the sea water at the surface, reduced to 60°, off San Francisco, was	1.026160
It gradually increased to	1.026960
And diminished again, near Acapulco, to	1.026520
From Acapulco towards Panama, it gradually decreased to	1.025920
And off Panama passed through streaks as low as	1.024600
On a former trip from Panama to the Galapagos and to Acapulco, the specific gravity in Panama Bay was	1.026160
March 6, 1888, in Lat. 3° 22′ N., Long. 86° 5′ W., on the way to the Galapagos, the surface water had a specific gravity of	1.025726
Off Hood's Island, " " " " " "	1.028316
Off James Island, " " " " " "	1.027916
In Lat. 8° 10′ N., Long. 95° 9′ W., the surface water had a specific gravity of	1.026316
Off Acapulco, the surface water had a specific gravity of	1.026924

The lines limiting the areas of specific gravities given on the chart by Buchanan in the narrative of the "Challenger" will have to be

modified as far as they relate to the Panamic District. According to the observations of the "Albatross," the specific gravities are too high off Panama.

Observations on the Pelagic Fauna by the "Challenger," and by Th. Studer in the "Gazelle."

Having always been more or less interested in pelagic faunæ, and having paid considerable attention to its vertical distribution during my earlier cruises in the "Blake," I was naturally anxious to reconcile the conflicting statements and experiences of the naturalists of the "Challenger" and "Gazelle" on one side, and my own observations on the other.

The subsequent observations of Chierchia, of Chun, and of Hensen, and their discussion, have only increased the interest in the problem of the bathymetrical range of the pelagic fauna. Before giving an account of the work accomplished towards the solution of the problem by the present trip of the "Albatross," I will rapidly give the results obtained since the "Blake" experiments.

It should be remembered that Studer's[1] statements were based entirely upon the assumption that the deep-sea Siphonophores, or their fragments, collected by him while in the "Gazelle" from the sounding line, actually came from the depths to which they were attached when the line reached the deck; so that, for instance, a fragment of Siphonophore coming up to the surface at the 650 fathom mark, or any other depth, indicated to Studer that the specimen was collected at that depth. From these observations Studer concluded that "auch die tiefen Wasserschichten nicht unbewohnt sind," and that they did not come from higher levels, the tow-nets of the "Gazelle" having frequently been lowered to a depth of 200 fathoms without bringing up any Siphonophores. He considers that the depth at which the Siphonophores occurred was a definite one, limited by the temperature,—a depth of from 800 to 1,500 fathoms, with a temperature of 2° or 3° Centigrade. The experiments of the "Challenger," on the other hand, consisted in sending open tow-nets down to various depths, and by a differentiation of the contents of the nets at different depths assuming that the changes in the catches were due to the several bathymetrical ranges of the species obtained. As the nets used by the "Challenger" were open tow-nets, all of which, on their way to the surface, passed through the upper and most

[1] Zeitschr. f. Wiss. Zool., XXXI., p. 1, 1878.

populous stratum of the ocean, it is evident that no great degree of accuracy in determining the bathymetrical range of the pelagic fauna could be claimed for this method of towing. From the mode of making the observations, the catch of all the hauls must have contained representatives of the fauna of the upper belts of water, regarding the geographical range and the composition of which we know as yet but little.

Observations on the Pelagic Fauna by the "Blake."

In spite, however, of the objections urged above, both Murray and Studer contended that, in addition to the deep-sea and pelagic faunæ, there was what might be called an intermediate fauna with characteristic species, having nothing in common with the other two; while I maintained, on the other hand, from my experiments in the "Blake," that there was no such intermediate fauna, but that the pelagic fauna might descend to a considerable depth during the daytime to escape the effects of light, heat, and the disturbing influence of surface winds, and that this surface fauna on the Atlantic side of the United States, off shore in deep water, did not descend much deeper than 150 to 200 fathoms, or some point not far distant from that level, depending of course to some extent upon the latitude of the observation; the lower bathymetrical limits of the pelagic fauna very probably coinciding with the limits to which the action of the heat of the sun, of light, and of other disturbing elements of the surface extended.

The experiments I made on the "Blake"[1] were carried on with the Sigsbee gravitating trap, which worked successfully, and tested the contents of a vertical column of water of any desired height. The only drawback of the original apparatus was its small size. The machine subsequently used by Hensen for his quantitative experiments worked on the same principle, of filtering the whole of a vertical column of water, and examining the results.

Observations on the Pelagic Fauna by the "Vettor Pisani."

The next observations made were those of the "Vettor Pisani."[2] Lieutenant Chierchia devised a net which he asserted could be sent down

[1] Bull. Mus. Comp. Zoöl., Vol. VI. Nos. 8 and 9, and Three Cruises of the Blake, Vol. I. p. 36.

[2] G. Chierchia, Collezioni per Studi di Scienze Naturali fatte nel Viaggio intorno al Mondo dalla R. Corvetta Vettor Pisani, Commandante G. Palumbo. 1885.

closed, then opened when it had reached the requisite depth, and after towing horizontally for a time closed by means of a propeller similar to the one adopted by Commander C. D. Sigsbee, U. S. N., for closing the water cups in use on the "Blake." Unfortunately, as experience has shown, all the experiments made by the "Vettor Pisani" are vitiated by the imperfect method of closure of the rim of the net, and the danger that it may open or close again and again on its way up to the surface should the hoisting be in the least irregular.

On the 31st of May, at a depth of 1,800 meters, a small net was attached below the thermometer, and tripped at the same time as the thermometer turned free of the propeller; but on examination of the figures of the net in use given on Plate X. by Chierchia, there is no doubt that he is correct in stating, "Anche in questo caso non si può asserire che tutta la quantità di animali trovati appartenga agli ultimi strati ove pescò il retino." So that this experiment at least proves nothing, the partly open net having passed through the upper 250 or 200 fathoms, where there is abundant life.

On the 5th of June the same experiment was again made on the "Vettor Pisani," at a depth of 1,000 meters; but there is nothing to show that, in the surging of the ship and the hauling up, the valves of the net have not opened and closed many times on its way to the surface. The same objection may be made to the haul of the 12th of June, at a depth of 2,300 meters.

The experience which all have had who have dredged at sea, of bringing up fragments of so called deep-sea Siphonophores, was of course also that of the "Vettor Pisani." Chierchia on the 24th of January, 1884, at a depth of 900 meters, let down the wire only, and brought up tentacles of Siphonophores. To insist, as he and Studer have done, that the depth at which these animals lived may be inferred from the length of the rope let out by which they reached the surface, is simply to ignore the fact that the wire rope on its passage upward through the pelagic belt of the fauna may catch anything within those limits. It will be seen that Hensen fully concurs with me in considering the bathymetrical data obtained by collections from the wire rope or the sounding line as of no value.

The fact that the "Albatross" on her last expedition brought up these so called deep-sea Siphonophores, from depths of less than 200 fathoms, in the open tow-net, which had not been sunk below that depth, ought to dispose of the argument of the wire rope catches as meaningless.

The two charts of Zootalassographia given by Chierchia for the Atlantic and Pacific show at a glance the general character of the surface fauna at the various localities at which the "Vettor Pisani" used the tow-net, and also in the Pacific chart the contents of the deep-sea net, and the depths to which it was lowered. But, as I have stated above, there is no proof as yet that the fauna and flora reported by the "Vettor Pisani" as living at the depths indicated by the record did actually live at those depths. We may leave out of consideration the catches of Siphonophores on the dredging and sounding wires, as well as a large number of hauls at depths of 100 to 400 meters, depths which are not in question; and as regards the contents of the self-closing net in use on the "Vettor Pisani," sent to depths in one case as great as 4,000 meters, it would add nothing to the discussion of the greatest depth at which pelagic animals are found, owing to the untrustworthiness of the working of the net. Of course, the same objections hold equally good to the results claimed from the contents of tow-nets sent to depths varying from 1,000 to 2,300 meters.

Observations on the Pelagic Fauna by the Prince of Monaco

In a German translation by Marenzeller[1] of the notices of the pelagic work of the yacht "Hirondelle" scattered through the Comptes Rendus, will be found an account of the experiments of the Prince of Monaco. Off Monaco he lowered a trap to a depth of 1,200 meters from the surface and 300 meters from the bottom, and obtained a species of Paralepis.

The Prince of Monaco has invented a number of most ingenious pieces of apparatus for collecting the surface fauna and that which may live at intermediate depths, but neither his apparatus nor that of Fol, who has experimented in the same locality, has been sufficiently tested to enable us to judge of its value.[2] Fol's apparatus, from his own account in "La Nature," is very sensitive to the rising and falling of the ship. The Prince of Monaco discarded the use of the Chun-Petersen net, as he found more or less gaping of the mouth frame, after it was supposed to have closed, during the whole of its ascent to the surface.

[1] Zur Erforschung der Meere und ihrer Bewohner, gesammelte Schriften des Fürsten Albert I. von Monaco, von E. v. Marenzeller, 1891.

[2] His large pelagic beam-trawl, if I may so call it, in use on the "Hirondelle," should prove a valuable machine for collecting surface animals.

The closing net of the "Hirondelle" for deep-sea pelagic work is a somewhat complicated and expensive piece of apparatus,[1] but appears to have worked well, although special data are not at hand regarding the exact depths of its working; and as is sufficiently clear, results obtained in the Mediterranean, or any closed sea like it, as the Baltic, or close to the shores of any mainland, cannot be correlated with those of the open sea, far from the disturbing factors at those localities.

Observations on the Pelagic Fauna by Dr. C. Chun.

The next experiments were those of Dr. Chun, who, under the auspices of the Naples Zoölogical Station, made an expedition to the Ponza Islands. Dr. Chun and the engineer Petersen applied to a tow-net an apparatus for closing it, similar to the propeller in use on our thermometers and water cups. Chun towed to a depth of 1,300 to 1,400 meters, but never at any great distance from the mainland or from the islands of the Gulf of Naples, and came to the conclusion that the pelagic fauna existed all the way to the bottom.[2]

In a notice of Chun's memoir on the results of this expedition, I questioned the conclusions to which he had arrived, and quote the following *résumé* from the American Journal of Science[3]: —

"Unfortunately, this expedition, interesting as its results are, does little towards settling the subjects under discussion, because neither the distance from shore nor the depths investigated were great enough to eliminate the disturbing effects of close proximity to land, as it was near the continental slope, on the very edge of which Dr. Chun trawled with the tow-net. The results are further vitiated from the fact that they have been carried on in a closed sea where the conditions of temperature are strikingly different from those of the Atlantic, and where at a depth of about 500 fathoms we find already the lowest temperatures of the deepest part of the Mediterranean. The minimum seasonal differences of temperature between that and the surface cannot be contrasted to oceanic conditions."

On his trip to the Canary Islands, his second pelagic fishing expedi-

[1] Compte-Rendu des Séances du Congrès Internat. de Zoologie, Paris, 1889, pp. 133–159.

[2] Bibliotheca Zoologica. I. Die pelagische Thierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächenfauna, 1887.

[3] A. Agassiz, in Am. Jour. of Science, Vol. XXXV. p. 421, May, 1888.

tion,[1] Chun was provided, as he says, with a line for pelagic fishing of a length of 1,600 meters.

During the journey Chun made seven casts, at depths varying from 500 to 1,600 meters. The casts are certainly not numerous enough to furnish a basis for a general theory. Two of the casts were at depths of 500 and 1,000 meters, not very distant from Cape Finistère, while another cast of 500 meters was made off Funchal, and the cast of 1,600 meters was made between Teneriffe and Gran Canaria, where he speaks of making a pelagic haul at a depth of 1,600 meters with a line only 1,600 meters long. He must, of course, have lowered his net vertically, and Chun can hardly expect any one practised in dredging or towing to accept the depth he gives as the correct bathymetrical limit at which the two specimens he brought up were collected. Furthermore, all of these casts except one, perhaps, are open to the objection of having been made at comparatively small distances from land; and, taking Chun's own account, the casts of 500 meters, say 250 fathoms, contain, judging from his list, about the same amount (somewhat less) of pelagic material as was found in our "Albatross" hauls with the tow-nets at depths of about 200 fathoms.

Furthermore, he says: "kam es bei den früherhin im Mittelmeer angestellten Versuchen gelegentlich vor dass durch den starken seitlichen Druck, welche die sich auslösenden Drähte auf den mit einem Schraubengewinde versehenen Messingstab ausübten, ein Öffnen und Schliessen des Netzes nicht erfolgte, anderseits blieb nach dem Schluss des Netzes gelegentlich ein schmaler, etwa fingerbreiter Spalt zwischen den beweglichen Hälften des Rahmens frei."

I need not say that an opening of half an inch wide and nearly two feet long at the mouth of the net will, in its ascent through a distance of 200 fathoms of the upper belt of the pelagic fauna, suffice to sift into the bag enough material to vitiate all accurate conception of what lives *below* that belt. In his expedition to the Canary Islands, these defects were said to be remedied by Chun, and the modified net was used by him during his voyage at depths of 500, 1,000, and 1,600 meters. But Hensen is of the opinion that the modified net is still defective, and that its results cannot be relied on. There seems to be no reason why these self-closing nets should not be placed serially on a line, as are thermometers, and then we may expect to get accurate results. If this be impracticable, we can, at any rate, use the nets at the same locality at

[1] Untersuchungen über die pelagische Fauna der Canarischen Inseln, von Carl Chun, Sitzungsb. d. König. Preuss. Akad. d. Wiss. zu Berlin, XXX., 1889, p. 519.

different depths, as I attempted to do on the "Blake," and have done more successfully on the present trip on the "Albatross." It is important to give at the same time the depth of the bottom and the distance from land, both most essential factors, to which neither Chun nor Hensen has paid sufficient attention.

In discussing the value of Chun's observations made on his way to the Canaries, we should remember that of the three casts with the closing net one was taken at a moderate distance off shore from Cape Finistère. The only strictly oceanic cast was his No. V., Lat. 34° 18′ N., Long. 15° 34′ W., and even that, if plotted, will be found remarkably close to the bank extending in a northeasterly trend from Madeira. This bank as marked is inside the 1,500 fathom line, and has many points the depths of which are near 500 fathoms. But leaving this out of consideration, his catch at that point consisted only of a single Copepod [1] and a Phaeodaria, and even these may have come from near the bottom. At any rate, we can hardly consider such a catch as indicating the presence at that depth of an abundant pelagic fauna.

As for the work accomplished by Chun at the Canaries, that strikes me as vitiated by the same disturbing factors to which I have already alluded. It can certainly not be called oceanic. The most distant of the Canary Islands is not more than 225 nautical miles from the coast, and the nearest less than forty, so that the pelagic fauna is under the influence, of all the disturbing elements of a coast line within a short distance. The very fact that so much surface pelagic material accumulates around the islands is the best evidence of this. We are therefore still left, so far as the distribution in depth of the pelagic fauna is concerned, to the few observations I made on the "Blake" (*pace* Haeckel), to that one of Chun mentioned above, to those of Hensen in the "National" expedition, and to those of the last expedition on the "Albatross." I am leaving out as not conclusive those of the "Vettor Pisani." The positive results of all these hauls clearly indicate that the bulk of the pelagic fauna is limited to a depth not exceeding 200–250 fathoms, and that then it rapidly decreases.

[1] The material collected by Chun was worked up by Claus in Arbeiten aus dem Zoöl. Inst. d. Univ. Wien, IX., 1890, I. p. 1. Of the new species described, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," six said to have been collected at 1,500 and 1,000 meters were also collected at the surface. No less than nine species have a wide geographical distribution, and those brought up from deep water in the proximity of land or near the Canaries of course add nothing to our knowledge of their oceanic bathymetrical distribution.

But until our reports give us the exact depth of the bottom, together with the results of the tow-nets from the so called intermediate deep-sea pelagic life, there is nothing to show that the contents of the nets may not have come from a belt of water close to the bottom, about which there has as yet been no discussion.

The occurrence of animal life within a moderate distance of the bottom is a question which is not to be confounded with that of the lower limit in depth of the pelagic fauna. These two zones may meet at depths of 500 to 700 fathoms, under favorable conditions of distance from shore, and give the impression of a continuous fauna from the surface to the very bottom. Undoubtedly a great deal of the confusion which has arisen regarding the lower limits of the pelagic fauna is due to differences in our understanding of what we call deep water. To a deep-sea dredger the limits of the bulk of the pelagic fauna, whether it turn out to be 200, or 250, or even 300 fathoms, is naturally shallow water. To one who has been accustomed to tow merely on the surface, 50 to 100 fathoms are already deep water, and depths below that seem enormous.

This last expedition of Chun — which made one oceanic cast! — marks, so Haeckel states, the greatest progress in marine biology since the "Challenger" expedition.[1] Yet he discards the results obtained from the oceanic hauls of the "Blake," which are the only accurate ones made up to the time when Hensen entered the field. He also considers Hensen's work worthless, probably because for over three months he explored the surface of the Northern Atlantic as it had not been done before. Unfortunately, Hensen's results do not chime with Haeckel's preconceived ideas, and they are naturally condemned because they do not show below 200 fathoms the existence of a populous pelagic fauna, which Haeckel had decided ought to exist down to great depths, and which he assumes the catches made by the defective net in use in the "Vettor Pisani" and those of the open nets of the "Challenger" to have conclusively proved. Taking all these positive results, as Haeckel is pleased to call them, and adding to them the equally fictitious statements regarding the presence of an intermediate pelagic fauna, based upon the fact that the so called deep-sea Siphonophores were found on the sounding wire and dredging rope of various expeditions, he gets a formidable array of incomplete data, brought together by defective methods. Upon these grounds he bases results for which more recent investigations, carried on with improved machinery, furnish as yet no

[1] I need not say that Chun makes no such ridiculous claim for his few experiments as are put forth by Haeckel.

proof. The later results are of course, as Haeckel says, in absolute contradiction to former experiences. Hence their great value, and the burden of proof is not upon the recent explorers, but upon those who build castles in the air based on the incorrect data obtained by the earlier expeditions. They have got to show that what they obtained from these great depths did not come from the upper belt of the pelagic fauna, from 250 or 300 fathoms in depth, up to the surface.

The Pelagic Fauna and the "National" Expedition.

It is a great merit of Hensen's [1] explorations, that he was the first to see that the quantitative measurements of the pelagic fauna could only be reached by the examination of the contents of a vertical column of water. This, if examined from the point of its minimum density upwards to the surface, will very nearly represent the total amount of life which lives in any given locality. We may by thus fishing upwards get at any locality practically all that is characteristic of it, whether the fauna has congregated at the surface or near it, or at any other part of the pelagic faunal belt, owing to the peculiar conditions of light, heat, wind, and weather.

In the "National" expedition in charge of Hensen,[2] the Plankton fishing hauls were limited to depths of 200 to 400 meters, and, if I understand the statements of Dr. Brandt [3] correctly, several hauls were made at the same spots to determine the vertical distribution of the pelagic organisms. A modification of the Petersen-Chun net was also used in the "National" expedition, and according to Hensen and Brandt there are still found in very considerable depths between the surface and the bottom "noch Organismen leben allerdings sehr viel weniger als in den oberen, von Licht durchstrahlten Wasserschichten." The number of indviduals decreased very materially the deeper the net was sunk, and there was also a rapid decrease in the number of species. Only Copepods and certain Radiolarians (Phaeodariæ) were found living at depths of 3,500 meters. Five casts from 3,500 to 2,000 meters contained nothing except Copepods and Phaeodariæ. Nearer the surface, from 2,000 to 1,000 metres, Sagittæ were added to the above groups, besides

1 Hensen, V., Ueber die Bestimmung des Plankton's. Fünfter Bericht der Kommission zur wiss. Untersuchung der deutschen Meere in Kiel. 1887.

2 Die Plankton Expedition von Victor Hensen, 1891.

3 K. Brandt, Verhandl. d. Gesell. f. Erdkunde, Berlin, 1889, p. 515. Ueber die biologischen Untersuchungen der Plankton-Expedition.

single individuals of Siphonophores, Craspedote Medusæ, Ostracods, Amphipods, Decapods, Salpæ, Doliolum, and young fishes. Eleven casts from 1,000 to 600 meters gave similar results, only the diversity was still further increased by the presence of Schizopods, Pteropods, Alciopidæ, and Tomopteridæ. How far these animals were the dead or recently dead carcasses of the mass of pelagic life living nearer the surface is of course not known, and, while hauling up from great depths through the column of water lying below the 200 fathom pelagic belt, we might expect a goodly number of such finds among the presumed inhabitants of the depths at which the self-closing net was operated.[1]

It must be remembered that, while many of the pelagic animals are most delicate, and decompose after death with great rapidity, yet when sinking from the surface towards the bottom these dead or dying organisms, soon reach a belt of water in which the low temperature as compared to the surface would prevent any very active decomposition, and the cold itself of the lower belts may be one of the causes of the limitation in depth of the bathymetrical range of the pelagic fauna. Moseley has found by experiment that a Salpa would take about four days to reach the bottom in a depth of 2,000 fathoms.

A few Velellæ, no Physalia, but a few Porpitæ, were met with, while Diphyes occurred in nearly all the hauls, either with the surface or with the vertical net. About twenty casts were made to determine the occurrence of organisms near the bottom, but owing to the failure of the sounding machine and its uselessness it was impossible to tell what the depth was, as the Sigsbee machine was not, according to Krümmel and Brandt, constructed according to specification, and gave out after the fifth trial; and hence no data of the depth of the bottom accompany the casts for the determination of the intermediate fauna.

To those of us who have been accustomed to fish for the pelagic fauna along the course of the Gulf Stream and off the east coast of the United States, it seems incredible, as is asserted by Hensen, that the pelagic fauna of the Atlantic is much poorer than that of the North Sea or the Baltic.

The success of the Plankton expedition in making their best surface hauls on the lee side of the ship is not a new experience to old fishermen. In all our dredging expeditions the lee side of the ship naturally has invariably been used to catch floating pelagic stuff, and the tow-net is always placed on that side. The floating tow-net of the "Hirondelle,"

[1] There being no description of Hensen's self-closing net, we cannot judge of the value of his results as settling the existence of a deep-sea intermediate fauna.

a pelagic trawl, seems to have escaped the notice of Brandt and Hensen, and a huge tow-net has been in use by the "Albatross" for many years.

I find it difficult to agree with Hensen's statement that it "is nonsense to think one can run the tow-net at a given depth horizontally, and that it is therefore mere waste of money to equip for this object." Certainly no one will claim to have towed along a mathematical line. All the variables which enter into the question as to the depth at which the net has been towed, — the speed of the vessel, the weight of the rope, its resistance as well as that of the net, and the shot which loads the extremity of the line, — undoubtedly make it a most intricate mathematical problem. But practically there is no such impossibility in keeping the tow-net within a very moderate distance of the required depth, and making constantly a careful record of the angle at which the line tends from the dredging boom. In our practice the net is first lowered vertically to the required depth, then the line is let out gradually, so that its length plus a small amount, taken from logarithmic tables, will represent the hypotenuse and catenary of the triangle along the base of which the net moves with a given speed which is carefully regulated by the angle of the rope. The shot used to sink the rope and net is a 200 pound shot, and a 60 pound shot at the end of the net halyards. This is about the weight of the wire rope to a vertical depth of 300 fathoms. The Tanner dredging quadrant angle-indicator[1] is in constant use to regulate the speed, and we feel satisfied from our extended practice that the difficulty of keeping the tow-net, say for fifteen or twenty minutes, at or near a given depth is comparatively slight, although the constant mathematical calculation of the exact position of the net is wellnigh impossible. The elements of error in estimating the height of the column of water passed through by the tow-net while towing vertically are equally great, and the same variables which Hensen enumerates as impossible of satisfactory reduction apply equally well to the rigid mathematical calculation of the height of the column through which the tow-net has passed. And yet he must be perfectly satisfied with his approximate measurement of that vertical column.

Hensen evidently does not think it of importance to limit the towing to a short column; his net closes after travelling 250 meters, and of course everything in that column is filtered through his net. Hensen has called attention to the danger of Chun's net opening on its way down, and also closing so that it would bring up nothing, leaving it

[1] Plate XXVIII., Appendix A, Report of the Commissioner of Fish and Fisheries for 1883, Washington, 1885.

uncertain whether the result was due to there being nothing at certain depths or to the action of the net itself.

While it is true that we made no volumetric or quantitative measurements of the material obtained by the tow-net, yet as we invariably used the same large pan, filled to about the same height, for the washing out of the contents of the tow, and as this water was then carefully examined in smaller dishes, it was not a difficult matter to make comparisons, which, though not quantitatively accurate as those of Hensen, yet differed sufficiently to show us a degree of variation in the quantity of pelagic animals far greater than that admitted by him. Hensen very justly says (p. 71): "Da sich die Massen im Ocean bei zu dieser Tiefe (400 m.), wenngleich mit abnehmender Dichte vertheilen, so ist es unzweifelhaft, dass dort selbst bei grossen Fängen die Dichte des Planktons nur gering ist." He adds in a note: "Die Bestimmung, wie die Massen nach der Tiefe zu abnehmen, erfordert genauere Analyse der gemachten Fänge, als bisher ausgefürt werden konnte; *die Hauptmasse findet sich meistens an der Oberfläche.*" The italics are mine.

It seems to me as if Hensen had himself given here an excellent reason for the value of fishing horizontally or in limited vertical ranges, neither of which he considers of any value.

Hensen's views regarding the depth at which the so called deep-sea Siphonophores exist are as follows: "Das Vorkommen von Fangfäden an Lothleinen [or also dredging wires] ist an und für sich überhaupt kein Beweis, den diese Leine geht zweimal durch die Oberfläche und kann hier alles fangen."

The discussion of Hensen regarding the accumulation of pelagic animals along extended rows I cannot understand. That such winrows exist near the shores he himself admits; that they are due near the coast to the greater or less interference of the complicated shore tidal currents seems to me self-evident. The action of counter currents and eddies complicated by the action of the prevailing winds is so well known to collectors at special localities that at certain stages of tide and wind one may feel sure of finding these accumulations at given points. That such winrows also occur on the track of great oceanic currents has been my experience in the Caribbean and Gulf of Mexico, in the Gulf Stream from 150, 200, or 250 miles from the coast, and that there they are also probably due to similar eddies and counter currents acted upon by the prevailing winds.

The Gulf Stream, with its ever fluctuating belts of currents, its rips, and the great Equatorial Current off Panama, with its bands of colder and

warmer water, its velocities from little or nothing to five or six knots, and its endless counter currents and eddies, did produce such winrows on several occasions at great distances from the shore, — over 600 miles. That these accumulations of pelagic animals on the surface are intensified on calm, brilliant days, goes without saying. How far they retreat below the surface when they disappear, we do not yet know. Such accumulations continue sometimes for a whole season on the surface. We have had at Newport Salpæ rendering surface fishing absolutely useless for more than six weeks, and again Ctenophores have been as great pests for as long a period, later in the fall.

The most extraordinary winrows I have met were off the Tortugas, about 150 miles to the northward, where the surface of the Gulf of Mexico for a whole day's steaming swarmed with Globigerinæ. It was a dead calm. Again, steaming from the Tortugas to Key West, a distance of sixty miles, outside the reef, we kept in sight a long comparatively narrow line of Linerges all the way from one locality to the other, and it extended eastward as far as the eye could reach beyond the entrance to Key West harbor.

Again, in the track of the Gulf Stream we passed for a quarter of a mile through a stretch of Trichodesmiæ of a width of about a hundred yards judging from the discoloration of the water. And in this last cruise, when about half-way from Cape San Francisco to the Galapagos, we remained for a whole day within the belt of a swarm of Nautilograpsus, the current running at the rate of nearly four knots in twenty-four hours. Again, for more than seven hours we steamed against a current of about three miles through a field of gigantic Salpæ, which extended on each side of the ship as far as one could see. Finally, we passed through winrows of a new species of Siphonophore, a gigantic species allied to Praya, which filled the water in compact masses on all sides of us as we slowly forced our way through it between our dredging stations on the way to Cocos Island from Point Mala.

Hensen, in his quantitative analysis of the pelagic fauna, does not seem to have given sufficient weight to the changes due to seasons, to currents and winds, and to local influences, and in his earliest experiments, dating back to 1882, and carried on from Kiel to the Danish islands, he has disregarded many important variables noticed by other observers.

He himself mentions the sudden occurrence, on the Scottish coast,[1] of

[1] We should remember that all observations made on the Scottish coast, the North Sea, and Baltic are within the area of the 100 fathom line, and at no great distance from land.

swarms of Limacina, and of Sarsia and Aurelia[1] in the Bay of Kiel, and contrasts these swarms with the poverty of the surface of the sea far from land. We are scarcely justified in assigning the presence of food as the cause of the sudden appearance or disappearance of these swarms of pelagic animals, and we cannot entirely agree with Hensen when he asserts that the Pyrosomæ, Salpæ, and Ctenophoræ occur in limited schools, depending upon the influence of the richer or poorer Plankton. A single day in a given locality is certainly not sufficient time to allow for such a change in the food supply of the sea as to account for the sudden appearance at sea or along our coasts of such masses of Salpæ, of Ctenophoræ, and of Diphyes as often render all attempts at surface or other pelagic fishing hopeless.

It is true that in our experience we have frequently (in the open sea) passed over extensive tracts where the surface fishing was comparatively unproductive; but we have rarely been twenty-four hours without finding some district which more than made up for the poverty of its neighborhood.

Haeckel's Plankton Studies.

In Haeckel's historical sketch of the study of the pelagic fauna,[2] no well informed reader can fail to notice the absence of reference to most of the work done by Americans in this field. Surely, no investigator is justified in omitting from a general review of this kind the older literature on the subject. We naturally suppose that no one willingly ignores the work of his predecessors, and, indeed, any one may be excused for not having at hand the latest pamphlet on a given subject. But there is no such valid excuse for disregarding contributions which date back ten or more years, and have been regularly noted in the annual reports of progress in zoölogy, in order to give undue prominence to publications which deal only indirectly with the subject in hand.

If Haeckel had taken the pains to look up the literature of his subject, he would have found that there has been a vast amount of surface work accomplished by the American dredging expeditions, and that, while it is true that much of this material has not as yet been worked up, still it is not probable that any sea-coast has been so carefully explored as has the east coast of the United States along its immediate shores, and along the course of the Gulf Stream, by the "Fish-Hawk," the "Blake,"

[1] Swarms of Aureliæ, forming huge patches which discolor the surface of the sea over considerable areas are not uncommon in Massachusetts Bay.

[2] Plankton-Studien, von Ernst Haeckel, Jena, 1890.

and more especially by the "Albatross," which has invariably, during more than six seasons, used the surface tow-net and an open deep-sea tow-net in connection with its other work, and which has been duly recorded in the Annual Reports of the United States Fish Commission.

As early as 1865, in the "Seaside Studies," a sketch of the pelagic surface fishing off the coast of Massachusetts was given. In addition to the chapter on the Pelagic Fauna of the East Coast of the United States given in the "Three Cruises of the Blake," papers on the surface fauna of the Gulf Stream, on the pelagic stages of fishes, and numerous notices scattered through various embryological and faunistic memoirs,[1] there is an account of the fauna of the surface water of the Gulf Stream off New England, drawn up by Professor A. E. Verrill[2] from the material collected by the United States Fish Commission during many seasons' work, up to 1883.

The "Albatross" used a number of muslin nets (silk bolting cloth), known as "trawl rings," attached to the ends of the trawl frame, so as to be somewhat above the bottom, and many pelagic species have been

[1] Seaside Studies, by E. C. and A. Agassiz, Boston, 1865.

See also remarks on the occurrence of pelagic types, by A. Agassiz, scattered through the following papers:—

The Embryology of the Starfish, 1864, reprinted in Mem. Mus. Comp. Zoöl., Vol. V. No. 1, 1877.

Revision of the Echini, Ill. Cat. Mus. Comp. Zoöl., No. VII. Part IV., 1872–74.

North American Acalephæ, Ill. Cat. Mus. Comp. Zoöl., No. II., 1865.

Surface Fauna of the Gulf Stream, Mem. Mus. Comp. Zoöl., Vol. VIII. No. 2, 1883, and other papers on the Embryology of New England and Florida Invertebrates.

Embryology of the Ctenophoræ, Mem. Am. Acad., Vol. X. No. III., 1874.

Pelagic Stages of Young Fishes, by Agassiz and Whitman, Mem. Mus. Comp. Zoöl., Vol. XIV. No. 1, 1885.

On the Young Stages of Bony Fishes. I. Proc. Am. Acad., XIII., 1877–78; II. Ibid., XIV., 1878–79; III. Ibid., XVII., 1882.

Bull. Mus. Comp. Zoöl., Vol. VI. No. 8, Letter No. 4, 1880.

Bull. Mus. Comp. Zoöl., Vol. VI. No. 9, 1880, Sigsbee's Gravitating Trap.

Am. Jour. of Science, 1888, Vol. XXXV. p. 421, Review of Chun's Die Pelagische Thierwelt.

Three Cruises of the "Blake," by Alexander Agassiz, Bull. Mus. Comp. Zoöl., Vols. XIV., XV., 1888.

And, finally, Three Letters from Alexander Agassiz to Col. Marshall McDonald on the Cruise of the "Albatross" in 1891, Bull. Mus. Comp. Zoöl., Vol. XXI. No. 4, published before Haeckel's Plankton-Studien had reached this country.

[2] Results of the Explorations made by the U. S. Fish Commission Steamer "Albatross," Lieut. Z. L. Tanner commanding, off the Northern Coast of the United States in 1883, by A. E. Verrill, Washington, 1885. Annual Report of the Commissioner of Fish and Fisheries for 1883.

obtained which have not occurred in the surface nets. Of course, as Professor Verrill remarks, it is impossible to know whether such species actually live at or near the bottom, at the surface or in intermediate depths, for they are liable to enter these nets at any time during the descent or ascent of the trawl, as well as during the time that it drags on the bottom.

There is also a more detailed account of the Medusæ collected by the "Albatross," by J. Walter Fewkes, in the Annual Report of the Commissioner of Fish and Fisheries for 1884, Washington, 1886; but to give the lists of depths, varying from the surface to 2,369 fathoms, of specimens brought up with the trawl or in the "trawl rings," does not add to our knowledge of the bathymetrical range of the Medusæ collected. These localities and depths would have supplied Haeckel with many valuable bathymetrical stations. It is astonishing that he should not have availed himself of such appropriate data.[1] We can only suppose that Haeckel wilfully ignores whatever does not bring grist to his mill, or does not chime with his preconceived notions of the order of nature.

If Haeckel had taken the trouble to read the statements I made regarding the bathymetrical range of pelagic life,[2] he would have found that I stated in the "Three Cruises of the Blake" (Vol. I. p. 37): "These experiments serve to prove that the pelagic fauna does not extend to considerable depths, and that there is at sea an immense intermediate belt in which no living animals are found, — nothing but the dead bodies which are on their way to the bottom." I may also refer Haeckel to another and similar statement in the same volume (p. 202), in the chapter on the Pelagic Fauna and Flora: "The above experiments appear to prove conclusively that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal life, between those living on the bottom, or close to it, and the surface pelagic fauna. It seems natural to suppose that this surface fauna only sinks out of reach of the disturbances of the top, and does not extend downward to any depth. The dependence of all the pelagic forms upon food which is most abundant at the surface, or near it, would naturally keep them where they found it in quantity." And again (p. 178): "How far down the pelagic fauna sinks during the day or night, to get out of reach of disturbances, is not

[1] Haeckel likewise omits all reference to the experiments of the Prince of Monaco, as well as those of Professor Fol off the Riviera.

[2] Bull. Mus. Comp. Zoöl., Vol. VI. Nos. 8, 9, 1880. Letter No. 4, on the results of the third cruise of the "Blake," and description of Sigsbee's gravitating trap.

yet accurately known; we can only form a rough guess from the few experiments made on the 'Blake.' . . . The lowest point is probably not far from 150 fathoms, which is perhaps the limit also of the greater superficial disturbances of heat, light, and motion, within which we may imagine the pelagic fauna to oscillate."

I also stated, in 1888 (Am. Jour. of Science, Vol. XXXV. p. 422): "Neither can the method adopted on the 'Blake,' of collecting at intermediate depths by means of the Sigsbee collecting cylinder, be considered decisive. It has not been tried long enough, or frequently enough, at great depths (it was not carried beyond 150 fathoms) to decide the depth to which the surface pelagic fauna might sink, or to prove the existence of an intermediate deep-sea fauna in the depth between the surface fauna and the deep-sea fauna."

I would also recommend to Haeckel's notice the following statement, by Murray, which is in full accord with the experience of the cruises of the "Blake" and of the "Albatross": "Mr. Murray's[1] researches led him to conclude that the great majority of pelagic organisms live at various depths, down to and even deeper than 100 fathoms, during the day-time and rough weather,[2] and only come to the surface during the night and in calm weather."

Both Thomson and I were careful to state that the question of the bathymetrical range of the pelagic fauna could only be definitely settled by the use of tow-nets so constructed as to tow horizontally at intermediate depths, and capable of being closed at will.

As for the proposition I enunciated that the deeper parts of the ocean contained no organic life, and not, as Haeckel says, "dass die Pelagische Thiere nicht tiefer als 100 Faden hinabgehen"; that must stand or fall, or be limited by explorations of a very different character from those of the "Challenger." It is childish for Haeckel to state that the so called exact experiments of the "Blake" are absolutely contradicted by the positive results of the "Challenger." If Haeckel is satisfied to base his

[1] Voyage of the "Challenger," Narrative of the Cruise, p. 218.

[2] Hensen considers the great percentage of water which enters into the composition of pelagic animals as a cushion against shocks, while the animals form, as it were, part and parcel of the surrounding medium. I may refer here to some measurements I made regarding the quantity of water entering into the composition of Echinoderms and Acalephs, which show how small a percentage of animal tissue they contain. For a large Cyanea there was no less than 99 per cent of water. The differences in the percentage of water contained in the tissues of pelagic types may account for their greater or less sensitiveness to the disturbing influences of waves and winds. See Proc. Bost. Soc. Nat. Hist., 1869, Vol. XIII. p. 107.

views on the population of the intermediate deeper parts of the ocean upon the positive results of the "Challenger" tow-nets, we must leave him to the full satisfaction of his belief. Haeckel's ideas of exact experiments must be very peculiar, if he imagines that an ordinary tow-net dropped to any depth, and then towed open all the way to the surface, will give us any exact data as to what is living at the deepest point reached. No amount of differential work will prevent that tow-net from gathering the pelagic fauna of the upper belt of 200 to 300 fathoms, which all the recent explorations at sea have shown to contain the greater mass of the pelagic fauna.

The dogmatic assertions of Haeckel regarding the value of the results obtained by the "Challenger" tow-nets are in marked contrast with the cautious statements of Sir Wyville Thomson, and they may be reproduced here for the benefit of Haeckel.

In the first place, the tow-net experiments of the "Challenger" were only conducted during the last part of the cruise: "In the investigations with the towing-net, made by Mr. Murray during the latter part of the cruise—at all depths, the nets being either sent down independently to the depths required, or attached to the dredge or trawl rope";[1] and while it is true that Thomson thought "that Radiolarians inhabit the water of the ocean throughout its entire depth, or, at all events, its upper and lower portions,"[2] yet we find in his summing up of the results obtained from the tow-nets the following statements: —

"We have every reason to believe, from a series of observations, as yet very incomplete, with the tow-net at different depths, that while foraminifera are apparently confined to a comparatively superficial belt, radiolarians exist at all depths in the water of the ocean. At the surface and a little beneath it the tow-net yields certain species; when sunk to greater depths additional species are constantly found; and in the deposit at the bottom, species occur which have been detected neither on the surface nor at 1,000 fathoms, the greatest depth at which the tow-net has yet been systematically used; and specimens taken near the bottom of species which occur on or near the surface give us the impression of being generally larger and better developed. The results from the tow-net are not so directly satisfactory as those from the trawl or dredge, which usually bring up animals which we know from their nature must have lived on the bottom, and it requires a little consideration to arrive at their precise value. . . . At present the tow-net, which

[1] Challenger, Atlantic, Vol. II. p. 341. [2] Ibid., p. 340.

consists simply of a conical bag of muslin or buntine attached to an iron ring, is constantly open, — descending, dragging along, and ascending. If worked on the surface there is of course neither difficulty nor question, but if brought up from 500 fathoms, at which depth it has been towing for some time, the net may be supposed to contain chiefly the species living at that depth; but mixed with these there must be a considerable number of more superficial forms, some taken when the net was going down with its open mouth downwards, and many more captured during its long ascent of half a mile through the upper layers. We cannot therefore as yet say with certainty whether the surface species live in the deeper belts or not, but we are justified in concluding that species which are absent on the surface, and present only when a certain depth has been gained, are special to that and probably to greater depths. If again species differing both from those procured on the surface and at intermediate depths are found in the bottom deposits, it is a legitimate inference that these live below the zone of our deepest tow-net observations." [1]

The expedition of the "National," much as it has been ridiculed by Haeckel [2] and his champion, Carus Sterne,[3] has done more to show that the pelagic fauna is a very scanty one to below 200 fathoms (400 meters) than all the work of all the other explorers together. The object was to work up the "Plankton." It is true it was not worked up according to Haeckelian methods,[4] but it has the immense advantage of being accurate, and not being based either upon guesses or upon misrep-

[1] Challenger, Atlantic, Vol. I. p. 236.

[2] In his attack on Hensen's work, Haeckel constantly refers to the "Ziele u. Wege der heutigen Entwickelungsgeschichte," Jena, 1875. In the present diatribe, he has almost surpassed his former achievements. Such contemptible attempts to overwhelm one's opponents with calumnies as are printed on pages 80 and 81 of the pamphlet referred to above are in accordance with his customary mode of argument.

[3] Rundschau, March, 1891.

[4] I quote from Hensen's Die Plankton-Expedition und Haeckel's Darwinismus, (p. 9): "Der Angriff auf die Expedition . . . kann vielleicht viel schaden, den er wird getragen von einer Autorität und wird begründet mit einer so grossen Anhäufung von einseitig gedeuteten Thatsachen, dass jeder mit dēn Verhältnissen nicht genau Vertraute davon überzeugt wird, dass die Plankton-Expedition völlig verfehlt sein müsse. Dennoch ist solche Ueberzeugung nur auf Sand gebaut und steht in völligem Wiederspruch mit den Thatsachen; und zwar nicht nur mit denjenigen, welche unsere Expedition nachweist, sondern, wie ich zeigen werde, selbst mit den Berichten, welche andere Expeditionen gegeben haben, sofern man dieselben nur richtig versteht."

resentations and scientific dishonesty, nor is it bolstered up or strengthened by abuse of one's opponents.

The majority of the organisms of the so called intermediate oceanic zones, as enumerated by Haeckel, have thus far proved to be inhabitants of the upper belt of less than 300 fathoms from the surface, and his attempts to subdivide this comparatively narrow belt of vertical distribution by expanding it to depths of which nothing is known, is thoroughly Haeckelian.

I can imagine no more disingenuous statement than the following, where Haeckel is speaking of Murray's account of the probable contents of the "Challenger" tow-nets coming up from great depths: "Er konnte aber dabei nicht dem Einwand entgehen, dass der Inhalt dieser beständig offenen bleibenden Taunetze aus sehr verschiedenen Tiefen, *oder auch nur von der Oberfläche stammen könne.* Den beim Heraufziehen des offenen Taunetzes konnten *möglicherweise* Thiere aus den verschiedensten Tiefen-Zonen *zufällig* in dasselbe hineingelangen." The italics are mine, and the kindness of the inhabitants of the deep in marshalling themselves, for Haeckel's[1] special edification, according to the depth from which they came, must be self-evident.

The subdivisions of bathymetrical distribution of the Radiolarians in the intermediate zones adopted by Haeckel are based upon the kind of evidence detailed above. Their true value, as well as that of the new nomenclature he has been good enough to flood us with in order to denote his imaginary bathymetrical ranges and their organic contents, can be accurately measured by those who do not allow themselves to be deceived by the dust and mud thrown up by Haeckel in the discussion of this subject.

I should be the last to question the indefatigable industry of Haeckel, which has produced the Monographie der Radiolarien, the System der

[1] It is one thing to clear up an old subject and introduce precision by a judicious manufacture of new terms, but it is quite another thing to burden a comparatively new and confused subject with such a superabundance of new names as are found in Haeckel's "Plankton-Studien." Moseley, in his Address on Pelagic Life, in 1882, was among the first to distinguish the different elements which go to form the pelagic fauna and flora, and his analysis has formed the basis of the endless subdivisions baptized by Haeckel. It is unfortunate that the value of Haeckel's analysis should be limited in so great a degree to his redundant terminology. Haeckel has enriched our nomenclature of deep-sea and pelagic faunistic combinations with a few dozen names which correspond usually not to anything known from observation or existing in nature, but to the pigeon holes skilfully put together by him.

Medusen, the deep-sea Medusæ, the Siphonophores, and the Radiolaria of the "Challenger" expedition. Yet I must remind the reader of Haeckel, that, in spite of the graphic account he gives of his own pelagic studies,[1] and in spite of his activity as a surface collector from localities near shore, he has had no experience whatever at sea of the sort of pelagic work which he so complacently condemns *ex cathedra*. The observations on the pelagic fauna on which Haeckel prides himself, made as a passenger in an East India steamer running from Suez to Bombay and to Ceylon, are of necessity, like its phosphorescent track, somewhat superficial.

The assumption made by Haeckel's satellite, Carus Sterne, that the cost of this expedition might have been saved had Haeckel been consulted as to its probable value, is as silly as it is unscientific. But it is fully in accordance with the dictum of the zoölogical pope at Jena that such an expedition was useless because he did not believe in its results. It is surprising that no one should as yet have objected to the cost of printing so many zoölogical fancy sketches as have come from Haeckel's facile pencil.

The account given by Haeckel of the distribution of the pelagic fauna and flora is premature, and as an accurate catalogue representing our knowledge is worthless. No attempt has been made to eliminate data which are in the least doubtful, but everything is enumerated as a correct observation of depth from the contents of the open tow-nets of the "Challenger" to the material brought upon dredging and fishing lines and in the imperfectly self-closing nets of the "Vettor Pisani." The material obtained by Chun in the Mediterranean is not compared with that of the oceanic basins, and of the doubts which Chun himself and Hensen have thrown on the efficiency of the Petersen-Chun net he does not even speak. As a mere enumeration of the surface material, Haeckel's account will be useful if the future observer learns to separate fact from fiction.

The first observations of Chun,[2] as I have already stated, were made comparatively near shore and in the Mediterranean to a depth of 1,400 meters, and the conditions existing there or in the deep fiords of the coast of Scotland are of no value regarding the extension of the pelagic fauna in an open oceanic basin; and it certainly is noteworthy that Hensen should have considered it sufficient to explore a belt of only 400 meters in depth, to get an adequate idea of the Plankton of the Atlantic Ocean, during the "National" expedition.

[1] Plankton-Studien, p. 16.

[2] Bibliotheca Zoologica, Heft I.

The regular appearance of certain forms at definite fixed periods has long been known to American investigators, as well as the periodic rising and sinking of fully grown forms of Salpæ and Ctenophoræ. But the facts seem to have had no value until rediscovered by Haeckel's friends.

It is not so astonishing as Haeckel seems to think that Hensen's results should be in direct opposition to those of the "Challenger"; the methods were entirely different, and the results of the "Vettor Pisani" were all vitiated by the serious defects of the net in use at great depths.

That I may not seem to be utterly prejudiced against Haeckel's methods, I will quote the views of one of the naturalists in the "National" expedition of the tactics in use by him: "Dass die Angriffe von Haeckel theils auf Mangel an Einsicht, theils auf Missverständnisse, theils endlich auf grobe Entstellungen und unverantwortliche Unrichtigkeiten in der Wiedergabe der Befunde anderer Forscher zurückzuführen sind."[1]

Observations on the Pelagic Fauna of the Panamic District by the "Albatross."

At every station we occupied, the surface tow-net was brought into requisition, and the contents of the net examined. The surface tow-nets, of about four feet in diameter, were made of muslin with a trap and a bag at the end of silk bolting cloth. A small net of finer bolting cloth was suspended in the centre of the opening of the net. This large tow-net was towed from the end of a boom off the ship's side when the speed of the vessel was sufficiently slow. A number of larger and more prominent surface animals were also constantly collected from the ship's deck with long hand nets. Excellent collections were invariably made with them when the electric light was lowered alongside. A very respectable collection of surface animals was thus brought together, which will form an interesting nucleus for comparison with the catches obtained by the Tanner tow-net at these same localities, either when dragged at definite depths, or when collecting on its way up from that point to the surface. As will be seen from the record of submarine tow-net stations (page 4), a number of collections were made which when carefully collated ought to give us important data respecting the bathymetrical range of the pelagic fauna.

In the Panamic region, currents from the west, from the north, and from the south meet, and then are diverted to a westerly direction, forming a sort of current doldrums, turning west, or east, or south,

[1] Brandt, Schriften des Naturw. Vereins f. Schleswig-Holstein, VIII., Heft 2.

or north, according to the direction of the prevailing current. The amount of food which these currents carry is small compared with that drifting along the course of the Gulf Stream. I was also greatly surprised at the poverty of the surface fauna. Except on one occasion, when during a calm we passed through a large field of floating surface material, we usually encountered very little. It is composed mainly of Salpæ, Doliolum, Sagittæ, and a few Siphonophores, — a striking contrast to the wealth of the surface fauna to be met with on a calm day in the Gulf of Mexico near the Tortugas, or in the main current of the Gulf Stream as it sweeps by the Florida Reef or the Cuban coast near Havana.

Although we often dredged in strictly characteristic Globigerina ooze or over bottoms containing numerous tests of Globigerinæ and Orbulinæ, I was much struck with the absence of living Globigerinæ on the surface. Only on two occasions during a calm did we come across any number of surface Globigerinæ and Orbulinæ. No pelagic Algæ were found, yet they occur in great fields off the west coast of South America as far north as Ecuador.

The number of new species which were constantly turning up in the contents of our tow-net, when hauled from 200 fathoms to the surface, plainly shows that no reliance can as yet be placed upon deductions drawn from the comparison of the contents of the nets at different localities and at varying depths. We evidently know as yet too little of the characteristic pelagic species living within the 250 or 300 fathom bathymetrical belt to enable us to state that the contents of open tow-nets lowered, say one to 500 fathoms and another to 1,000 fathoms, no matter how different they may be, are not due to the pelagic fauna living in the upper belt between the surface and 200 or 300 fathoms.

I am not questioning the existence of pelagic, or rather free-swimming species, at a moderate distance from the bottom, nor the presence near shore of such animals at considerably greater depths than those to which the oceanic pelagic fauna extends, or at short distances from shore, where an archipelago may form a barrier, as do the Canaries or the West India Islands, to the free action of oceanic currents, and where pelagic species may accumulate under radically different conditions from those of adjoining oceanic basins.

Too little is as yet known of the geographical distribution of the oceanic pelagic surface organisms of either the Atlantic or Pacific Ocean.[1] We know, it is true, something of their geographical distribu-

[1] See an interesting note by Chun in the Zool. Anzeiger, Nos. 214, 215, January, 1886.

tion along our coasts. We can distinguish, to a certain extent, an Arctic, an Acadian, a Virginian, or a West Indian district, as it were, among the Acalephs and other pelagic forms close to our shores. But when we come to attack the problem of the distribution of the pelagic forms of the oceanic basins, we are at a loss, with our present knowledge, to recognize anything beyond geographical realms practically corresponding to the arctic, temperate, and tropical regions of the oceans. The results of the only expedition which has as yet made a preliminary survey of the North Atlantic are not published, and they will probably show us how complicated the problem is when examined with reference to both a horizontal and a bathymetrical range. This part of the problem has been ignored by Haeckel.

To satisfy ourselves of the difficulty of determining the bathymetrical range of pelagic animals by differentiation of the contents of tow-nets sent down open to tow at different depths, we spent some time at Station 3282 in sending open tow-nets to 100 and 200 fathoms, and also at two other stations, with the following results.

On March 7th we lowered a large surface tow-net to a depth of 200 fathoms, and towed at that depth for fifteen minutes, bringing the open net rapidly to the surface at the usual rate. This trial was made at Station 3382, the bottom depth being 1,793 fathoms, the distance from the 100 fathom line about sixty miles, and the distance from land seventy miles.

The bulk of the material collected consisted of masses of a small species of Doliolum and of Sagitta, among these many of the large species of these genera previously mentioned. Among the other pelagic material were to be found the separate bells of the large Siphonophore first observed off Mariato Point, fragments of an Agalma as well as of the huge Pterophysa so often brought up on the dredging-wire rope, many bells of Crystallodes, and species of Diphyes. The other Acalephs were represented by species of Cytaeis, of Liriope, of Æquorea, of Saphenia, of a Melicertum-like genus, and a Stomobrachium, a very delicate pyriform Mertensia remarkable for the great length of its funnel, a Cunina, and a Discophore allied to Nauphanta. The Heteropods were represented by a species of Firoloides. Finally, the surface swarmed with Orbulinæ having an orange-red nucleus; also specimens of Polyipnus and of another Scopelid, of Gonostoma, and of a small fish allied to Astronesthes, several species of delicately tinted rose-colored shrimps in different stages of growth, as well as many larval stages, specimens of Phronima and Hyperia, many young Squillæ, a large semi-transparent Calanus, many Copepods, and many species of Sergestes.

A second haul was then made with the open tow-net from the 200 fathom level to the surface without towing at that depth. The net was drawn up more slowly, but the contents of the net differed in no way from the preceding hauls, except that the quantity of pelagic life obtained was naturally much less than when we spent in addition fifteen minutes in towing at the 200 fathom level. In hauling the net from 100 fathoms to the surface in a still shorter time, the amount of material was still more reduced. The surface tow-net contained scarcely anything, the sea being quite rough, a fresh trade wind blowing.

These hauls, made with open tow-nets, showed little variety in the constitution of the pelagic fauna at 100 and 200 fathoms, the surface animals having been driven to deeper waters by the disturbed state of the upper layers. We obtained nothing in the hauls from 100 and 200 fathoms which had not on some other occasion been obtained in the surface tow-net, though not in as great quantities as when towing at greater depths.

On the evening of the same day, it being calm, the surface tow-net was crowded with Nautilograpsus, and contained also nearly every species we had caught in the morning while towing at depths of 100 and 200 fathoms, and the number of specimens was quite as large as in the greater depths. The Stomobrachium, Liriope, and Saphenia, and likewise the Diphyes and Crystallodes, were more numerous perhaps, while Doliolum and Sagitta constituted the bulk of the material of the tow-net.

On the 9th of April, the Tanner net was sent down to tow at 175 fathoms, and thence hauled open to the surface. The net contained numerous specimens of Doliolum, Salpæ, Sagittæ young and old, transparent Annelids, Tomopteris, masses of Copepods, Leucifer, Sergestes, Schizopods, Sapphirina, Hyperidæ, Phronima, Ostracods, a few small Stomobrachium and Liriope, and numerous bells of three species of Diphyes and of Crystallodes, a few specimens of Pneumodermon, of Atlanta, of Hyalea, and of Creseis, and the same species of Rhizopods found in the surface tow-net at the same locality. No fishes were obtained in this haul.

The haul of the surface tow-net at this locality, though towed on a smooth and calm sea in a bright sun and with no wind, was comparatively poor. The Rhizopods were more numerous than from the deeper haul, but the number of species and of individuals of the Crustacea, Worms, and Siphonophores was much smaller, and there were no Pteropods.

Copepods with large blue eggs were obtained in both these hauls,

which were made about 300 miles southeast of Acapulco, and the depth must have been about 2,200 fathoms, as we were near soundings of over that depth.

The same evening, about 250 miles from Acapulco, with a smooth sea which had continued all day, we towed the surface tow-net, carrying the electric light alongside. The net contained small Sagittas, Diphyes, Doliolum, and Hyalea. A great number of Halobates were attracted by the electric light, and caught with hand nets; flying-fish of all sizes were darting about the electric light. The motion of the flying-fish could readily be followed in the water. They used their huge pectorals with extraordinary skill; opening and shutting their wings rapidly, they regulated their speed with ease, and by suddenly opening or shutting either wing, and planting it at a right angle to their course, they managed to check and change their motion and direction instantaneously. Either wing might in any stage of expansion be fully spread out or closed like a fan, and the wings were in constant play, opening and shutting their powerful fans to control their movements. We can understand how readily they manage to escape the attacks of fishes following them from below in the water, or of aquatic birds darting at them from above the surface. The surface net also contained Pteropods, Atlanta, Creseis, a large number of Schizopods, Sergestes, Leucifer, bells of Crystallodes, and numerous small Stomobrachium and Liriope, pelagic Annelids, Copepods, Sapphirina, Glaucus, Firoloides, and pelagic flounder embryos. The number of specimens of Sagitta was extraordinary; they practically filled the net.

In the evening the Tanner tow-net was also sent to 175 fathoms, where it was towed for ten minutes, and the messenger sent down to close it. The lower net came up well filled with the surface pelagic species, which on this day were unusually varied, it having been smooth and calm the previous night, and the morning before the towing was made. But the quantity of animal life was much less, although the deep haul was continued longer than the surface towing. So that on this occasion the bulk of the pelagic fauna was evidently nearer the surface.

The Acalephs of the Panamic District.

As far as I could judge from a preliminary examination of the fragments of Siphonophores and of the specimens in more or less perfect state of preservation brought in by the surface tow-nets and the Tanner

net, as well as in the trawl and attached to the dredging rope, the following are the genera which were noticed by us: Anthemodes, Bassia, Agalma, Athorybia, Crystallodes, Nectophysa, Pterophysa, Rhizophysa, Velella, Porpita, Physalia, Praya, Diphyopsis, Diphyes, Abyla, and Cymba.

Crystallodes and the genera of Diphyes were by far the most common of the Siphonophores; we scarcely made a haul of the tow-net without finding some bells or fragments of these two groups.

The other Acalephs were not numerous in species, although sometimes we passed through great numbers of a large species of Liriope, and some of the Ctenophores, of which a species of Mertensia and a Mnemiopsis were the most common. Ocyroë was observed once, Idya was comparatively rare, and Cunina was found occasionally, while the trawl and tow-nets frequently brought up Periphylla, Drymonema, Nauphanta, Atolla, Stomobrachium, an Æquorean allied to Tima, genera allied to Saphenia, to Melicertum, to Lizzia, and to Cytæis, and a genus allied to Rathkea.

Observations on the Pelagic Fauna of the Intermediate Depths in the Panamic District, made by the "Albatross" with the Tanner Tow-net.

As I stated at the time Chun published the results of his first experiments, I considered them inconclusive,[1] and was of course anxious to repeat them in a strictly oceanic district, in great depths, and at a considerable distance from shore.

On Plate I., I have given figures of a slightly modified Chun-Petersen tow-net, which was constructed by Ballauf, of Washington, for my use on this expedition.

Figure 1 shows the closed net ready to lower; Figure 2, the net opened, ready to tow at the required depth; and Figure 3, the closed net on its way up. *f* is the metal frame protecting the propeller *p*. The propeller shaft extends to the crossbar *c''*, fitting into a socket from which it is relieved after a few turns of the propeller, when the net is first moved horizontally, and liberates the rings of the chain *b* from the bar *c''*, and thus opens the jaws of the net, bringing the strain on the two parts of the chain *a*. As soon as the propeller shaft passes beyond the crossbar *c*, the upper parts of the chain *a* are relieved, and it then becomes the longest, and the strain comes upon the chain *b*, which pulls

[1] Am. Jour. of Science, 1888, Vol. XXXV. p. 421.

together and closes the jaws of the net at the termination of the time of towing, and it remains closed until it reaches the surface.

The 25th of February we made our first attempt with the modification of the Chun-Petersen closing net for towing at intermediate depths. On towing the same horizontally near the surface, so that we might watch the operation of the propeller in releasing the chains to open and then to close the net, it became very soon evident that but little reliance could be placed on the working of the propeller from the great pressure brought upon the shaft even during the slowest towing; and from this the uncertainty of the action was so great that we could not feel satisfied that the net had closed and opened at the limits within which it was supposed to act. A very small net might work satisfactorily on this principle, and prove useful for attachment to a line for simultaneous serial observations after the fashion in use for serial thermometric work. This was a great disappointment, as from the first account given by Chun I inferred that there were no drawbacks to this machine. He mentions them in the account of his voyage to the Canary Islands. After this failure, we made no other attempt to use the machine, and subsequently our fishing at intermediate depths was carried on with the Tanner self-closing net, a description of which is given further on.

Thanks to the ingenuity of Captain Tanner, we overcame these obstacles. He devised a net which could be closed at any depth by a messenger, and which worked to perfection at 200, 300, 400, and 1,000 fathoms, and had the great advantage of bringing up anything it might find on its way up above the level at which it was towed.

Figure 1 of Plate II. shows the general arrangement of the Tanner deep-sea closing net attached below the heavy shot, *a*, at the extremity of the wire dredging rope, *r*. The net itself is suspended between two ropes, *r'*, *r'*, to which a sixty-pound shot, *b*, is suspended; the extremity of the net is kept in place by a slack line, *r''*. Around the lower part of the net a set of rings is fastened, through which passes a loop line, going out through pulleys, *p*. At each end of the loop line is fastened a fourteen-pound lead weight, *w*, which is hung close to the pulley by strings, *l' l'*, suspended by loops from a crank, *t*; this crank is securely fastened to the wire rope by a clamp, *n*, the details of which are seen in Figures 4 and 5.

The outer net is made of twine netting, with a mesh for the support of the thinner and weaker muslin which lines the lower half of the net; this in its turn is lined for its lower half with fine close-mesh silk bolting

cloth. The net is lowered with the open frame (as represented in Fig. 1) uppermost, at the rate of about 100 fathoms in four minutes; when the net reaches the requisite depth at which it is to be towed, sufficient slack of wire is let out, so that the angle of the wire rope due to the speed of the vessel will keep the net towing at a nearly uniform depth. It is usually towed for twenty minutes, when the speed of the vessel is slackened, as the rope is wound in, until the net is vertical when the ship stops; the messenger, *m* (Figs. 1, 2), is then sent down on the wire rope, and, striking the crank *t*, trips it, and it drops to the position *t'*, as seen in Figure 4. This liberates the loops of the string *l l*, by which the weights *w w* are hung; these drop rapidly to the position *w w*, as seen in Figure 6, pulling both together, and closing tightly the loop which passed round the lower part of the net. The net is then hauled up at the same speed at which it was lowered, and invariably comes to the surface with the bottom part tightly closed. The upper part of the net above the loop remains open, and collects anything found on its way from the depth at which the towing was made to the surface. When the net reaches the surface, the loop closing the net is at once supplemented by winding below it a stout twine; the bottom fastening of the net is then opened, and the inside net carefully washed in filtered sea water, and that in its turn carefully examined.

Figure 2, the messenger *m* (made in halves), showing the grooves, *s*, by which it is fastened to the wire rope *r*.

Figure 3, the extremity of the dredging-wire rope, with its weight, from which the net is suspended.

Figure 4, showing the clamp attached to the wire rope *r*, with its crank, *t*, from which are hung the loops of the line *l*, holding the weights *w w* suspended; *t'* shows the position of the crank after it has been tripped by the messenger *m*.

Figure 5, the same as Figure 4, seen from above.

It will be noticed that we used no contrivance by which the Tanner net was sent down closed, and subsequently opened when at the required depth. To obviate this difficulty, we loaded the wire rope with a heavy shot, *a* (Figs. 1, 3), to counterbalance its weight, and in addition attached to the bottom of the guides of the Tanner net a heavy weight, *b* (Figs. 1, 6), so that, when lowering the apparatus slowly, the net was sent down with the closed extremity leading. In this way the pressure of the water on the bag of the net kept the lower part of the sides closely compressed together. Water passed through only the upper open parts of the net, close to the mouth frame, where the meshes are those of an

ordinary bait hand-net. As there is a double net of muslin and of fine silk bolting cloth extending half-way up the net, everything is kept out of the net on its way down. It is an interesting experiment to drag a tow-net through the water with the closed point leading, and to observe how completely the sides are collapsed, and prevent the admission of water into its lower extremity. The water in the pans in which the contents of the net were to be washed was always carefully strained through fine silk bolting cloth, as was done on the "Blake" with the Sigsbee trap. Two pans were thus prepared, one for the contents of the lower part of the net, — the closed part, — the other for the examination of the contents of the upper part of the net, which remained open all the way from the level at which the net was towed to the surface.

On the 9th of March, at Station 3388, at a depth of 1,168 fathoms, fifteen miles from the 100 fathom line and twenty-five miles from the nearest land, we made our first trial of the Tanner net. Before sending it down to the deeper belts, it was tried near the surface within sight, and, the performance of the messenger and the action of the closing weights having proved satisfactory, it was sent to tow at a depth of 400 fathoms, and towed for seventeen minutes, the ship being carefully slowed so as to keep the depth nearly uniform, and then the length of the wire rope gradually reduced from 570 fathoms, the length of line let out on the hypotenuse, to 400 fathoms vertically. The angle of the line was carefully checked the whole time by means of Captain Tanner's goniometer, so that the variation in the depth at which the net was towed could not amount to more than a few fathoms. The messenger was then sent down to liberate the weights hanging from the slings suspended upon the crank of the stopper, which were to close the bottom part of the net. The net was then hauled up at a speed of about four minutes to the 100 fathoms, so that for some sixteen minutes the upper open part of the net was scooping in the pelagic life in its track. When the Tanner net approached the surface, it was found that the bottom part of the net had been securely closed, as represented in Plate II. Fig. 6. The bottom part of the net was opened after having tied securely the upper end of the bottom of the bag, below the loop, to prevent any part of the contents of the open part of the net from falling into it. The lower part of the net was then carefully washed out in water which had been filtered, and that water was then examined. There was absolutely nothing found in the water. On the other hand, the upper part of the bag, which had remained open the whole way up from 400 fathoms to the surface, was found to contain very much the

same species we had obtained when towing with the open surface net from a depth of 200 fathoms, two days before, at Station 3382, a distance of about sixty miles. We brought up, in addition to the species obtained at that station, Pyrosoma, Benthoteuthis, a number of Sternoptyx, some of them quite small, not measuring more than half an inch in length, Scopelus, Stomias, Gonostoma, Astronesthes, Melamphaës, Plagusiæ, a fine black Beryx-like fish of a new genus which we had brought up alive in the trawl at Station 3383, and which evidently is not a bottom fish, while I had assumed at that time that it might come from 1,832 fathoms. We also brought up in the open part of the net a number of young Eryoneicus, from half an inch to an inch in length. Our first specimens of the genus came up in the trawl at Station 3375, depth 1,201 fathoms, afterwards at Station 3377, depth 764 fathoms, and, before we lowered the Tanner net, the trawl at Station 3388 had also brought up a fine large specimen of this genus, which we then considered to have come from a depth of 1,168 fathoms. But it is more probable that even the old of this genus, with their huge swollen cephalothorax, are peculiarly adapted to float passively, and live in the intermediate belt between the surface and the deepest point to which the pelagic fauna may extend. At the time the haul with the Tanner net was made, it was blowing quite a fresh trade wind, and it was a favorable day for deeper hauls, as the disturbance of the surface had been great during the earlier part of the day and the preceding night.

On the 11th of March (at Hy. Station No. 2619, depth 1,100 fathoms) the Tanner net was sent to tow at a depth of 300 fathoms. We paid out 430 fathoms of wire rope and towed nineteen minutes. The extra length was slowly taken up, until the line became vertical. The messenger was then sent down to detach the closing weights, the time of the messenger to reach the tripping crank being two minutes and twenty seconds. The time can readily be ascertained by retaining a hold of the wire rope, as the shock of the striking messenger can be most distinctly perceived on deck. The net was then hauled up at the usual rate of about 100 fathoms in four minutes. The Tanner net reached the surface with the bottom of the bag well closed. The same precautions were taken to isolate the lower part of the bag, and with the water in which the net was washed, as on the first trial. As then, we found that the lower part of the bag, closed at 300 fathoms, again contained absolutely nothing.

The upper part of the net, which remained open all the way from 300 fathoms to the surface, contained the same amount and quality of material we had obtained on the first trial. There were, perhaps, not so

many specimens of Doliolum, but the same types of Crustacea, Copepods, Macrurans, and Siphonophores, the same species of fishes, with a different larval Plagusia from that of the former haul, characterized by a dark violet black longitudinal band along the flanks, and a young Octopus.

Immediately after the above trial, at the same station (Hy. Station 2619, depth 1,100 fathoms), we sent down the Tanner net to tow at a depth of 1,000 fathoms, to endeavor to ascertain what might be obtained by towing as nearly as possible about 100 fathoms above the bottom. We let out 1,160 fathoms of wire rope, and towed for nearly sixteen minutes; the extra length of rope was then slowly wound in to bring it vertical, and the messenger was sent down to trip the crank; the time of the messenger in reaching the detacher was seven minutes and thirty-five seconds; the Tanner net was then hauled up at the usual rate of four minutes per 100 fathoms, and the customary precautions used in examining the contents of the upper (open) and lower (closed) parts of the net. A sounding was taken immediately after the net came to the surface, and we found that during the time we trawled and towed we had drifted into a depth of 1,482 fathoms, so that we failed in the immediate object of our trial. We found in the closed net a large violet Amphipod, and a brilliant carmine shrimp, of the usual color of the deep-sea Macrurans. These two specimens must have come from a belt of not more than 350 fathoms above the bottom, and were different from anything we had collected before. The open part of the bag contained an Atolla, a fine specimen of the pink Stomobrachium, both probably from a comparatively moderate depth, judging from their perfect state of preservation. The same Crustacea and fishes came up as on other trials in that part of the Tanner net, and also a fine orange Amphipod like one brought up in the trawl at Station 3383, and assumed then to come from a depth of 1,832 fathoms. The open net also contained a huge Noctiluca, measuring about half an inch in diameter, with a peduncle fully ten times the diameter of the disk.

On the 25th of March, at a point not quite half-way between Cape San Francisco and the Galapagos, Hy. Station 2627, the depth being 1,832 fathoms, the Tanner net was sent to tow at a depth intended to be about 100 fathoms above the bottom, and which varied from 1,773 fathoms to 1,739. Within these limits the net was towed for twenty minutes, the same precautions being taken to bring the wire rope gradually vertical before the messenger was sent down to close the net; the messenger was seven minutes in reaching the detacher. The net was then hauled up, and the contents of the lower part, which

had closed, were carefully examined, using the same precautions to strain the water of the pans as on former hauls. With the exception of the fragments of a few decayed leaves, evidently caught while on their way to the bottom, the net contained nothing; it was barren of animal life.

The upper part of the Tanner net, which had remained open all the way to the surface, brought up the same species which on former occasions the net contained when towing at a depth of 200 fathoms from the surface. There were found a great number of small Doliolum and of a large Sagitta. The number of individuals as well as of species of Crustaceans in this haul was very marked. Several species of Leucifer, of Sergestes, of Schizopods, Copepods, and of highly colored Hyperiæ probably parasitic on a Salpa, which was abundant, as well as a number of Macrura fully as bright red as any of the deep-sea Schizopod types, in addition to the transparent pelagic types. We also obtained a Stomobrachium, a large Beroë measuring nearly six inches in diameter, a number of bells of Diphyes, and a huge Ostracod allied to Crossophorus, with a thin membranous test, — a giant of its kind, measuring somewhat more than an inch in length. The largest Ostracod previously known is not more than one third of an inch long. The pelagic Benthodytes, which first came up in the trawl at Station 3,364, also occurred in the open part of the net.

Among the so called deep-sea Medusæ several specimens of Atolla and of Periphylla were found in the open part of the net. The net also contained a Leptocephalus and two other species of fishes, the one allied to the Scopelids, the other to the Stomiadæ, many of which have been regarded as typical deep-sea forms.

The surface at this point was also examined with the tow-net, and the pelagic animals found to be the same as those brought up in the open part of the Tanner tow-net on its way from the bottom. The number both of species and specimens was, however, much less than in the Tanner net.

On the following day, March 26, the Tanner tow-net was sent to be towed at a depth of 204 fathoms. After twenty minutes the messenger was sent down and the net hauled up. The bottom part of the net came up tightly closed. Its contents were examined in the same manner as before, in well strained water, and the water was found to be absolutely barren, while the upper part of the net, which came up open and was not more than eight or nine minutes on the way, was only fairly filled with surface life. The upper net contained a few specimens of

Doliolum, Sagitta, Hyalea, Creseis, and a couple of species of Macrurans. The poverty of this deep haul may be accounted for by the corresponding poverty of the surface. The surface tow-nets hauled for nearly twenty minutes contained scarcely anything beyond a few Sagittæ, Appendiculariæ, Copepods, and pelagic fish eggs, and perhaps a larger number of bells of Diphyes and Crystallodes than in the Tanner net; yet the sea had been smooth during the night, and up to 9 A. M., the time of the haul, not a breath of wind had ruffled the surface. Our position, Hy. Station 2628, was a few minutes of latitude south of the equator, about 250 miles from the Galapagos, and about the same distance from Cape San Francisco; the depth probably between 1,500 and 1,800 fathoms. Soon after, the open tow-net was also hauled from a depth of 200 fathoms up to the surface. In addition to the species enumerated above, we obtained Sergestes, larvæ of Penæids, a bright yellow Æolis, a large Stomobrachium, and numerous bells of Crystallodes and Diphyes. The wire rope passed through myriads of Nautilograpsus swarming on the surface; they literally choked the surface tow-net.

On the 8th of April, about 7 A. M., Station 3414, depth 2,232 fathoms, 350 miles from land, the sea was quite rough, a heavy swell rolling, and the trade wind was blowing briskly; the Tanner net was sent to tow at 100 fathoms and closed by messenger; time of messenger in reaching the detacher, forty-five seconds; after towing the net about twenty minutes, it was hauled up to the surface. The lower closed part of the net, and the upper part, which had remained open the whole time, contained the same species. The lower part of the net contained a good deal more animal life, having been towed for twenty minutes at about 100 fathoms from the surface, while the contents of the open upper part passed through 100 fathoms in about four minutes. The haul of the upper net consisted of a large red Cypris, a small transparent cuttle-fish, a few Doliolum, a large pinkish Hyperia, a large Cystisoma parasitic on Doliolum, Sapphirinæ, transparent Penæids, bells of Crystallodes and of two species of Diphyes, fragments of Beroë, a number of Collozoum colonies, and Calanus and other Copepods. The lower net contained the same things, the Sapphirinæ and Hyperiæ being rather more numerous, and a few specimens of Atlanta which had not been obtained in the haul of the upper part of the net from 100 fathoms to the surface.

An hour later, the Tanner net was sent to tow at a depth of 200 fathoms. After towing for ten minutes the messenger was sent to close the net, the dredge rope having, as in all cases of towing at intermediate depths, been gradually brought to be vertical before the net

was closed. We found in the lower closed part of the net, in addition to the same shrimps and Copepods obtained from 100 fathoms, Firoloides, Mertensia, and a small Sagitta. In the upper part of the net, which was towed open from 200 fathoms to the surface at the rate of four minutes to 100 fathoms, the animal life consisted of the same species as in the lower part of the net, and in addition the *tasters* of a large Pterophysa fully two and a half inches long, — the same species fragments of which so frequently came up on the dredge rope, — specimens of a large and of a small Sagitta, two species of Phronima, a Typhis, and two species of Salpæ; the Doliolum were more abundant than in the lower depths. Fragments of the bell of a large Diphyes of an unknown genus, from two to three inches in length, with a delicate yellow stem, and a few bells and fragments of another species of Diphyes and of Crystallodes, and a few specimens of Scopelus. Time of messenger in reaching the detacher at 200 fathoms, fifty seconds.

At this same station the Tanner net was next sent to tow at 300 fathoms, but, the detacher lines having got entangled with the dredge-rope swivel, it failed to close, and came up open all the way to the surface from 300 fathoms. The contents of the open net were identical with those of the previous haul from 200 fathoms to the surface; we added, however, a number of young specimens of Sternoptyx. The net was sent again to tow at 300 fathoms, and the messenger sent to close the net after towing fifteen minutes; time of messenger in reaching the detacher, two minutes and forty seconds. The lower part of the net came up well closed, and its contents were carefully examined, taking the usual precautions. The lower closed part of the bag contained nothing. The upper open part of the net contained Sternoptyx, Stomias, Scopelus, a small violet cuttle-fish, and a number of Schizopods, Euphausiæ, Thysanopodæ, Siriella, Nyctiphanes, Eucopia, and the like, apparently identical with those found in the hauls from a depth of 100 and 200 fathoms to the surface. Many of the same Crustacea (Schizopods, etc.) were also obtained in the surface tow-net at this locality, although the wind and swell continued during our experiments, and the surface was greatly disturbed.

On the morning of the 11th of April, the Tanner net was sent to tow for twenty minutes at a depth of 300 fathoms, at a locality about thirty miles southeast of Acapulco, at a depth probably of over 1,800 fathoms, the surface being moderately rough, a light wind having blown all night. The messenger was sent to close the net after the usual precautions, time occupied three minutes and fifteen seconds, and the net hauled

rapidly to the surface. The lower part of the net had closed satisfactorily, and on examination was found to be barren of animal life, even at so small a distance from the land. The upper part of the net contained an unusually rich assortment of surface species, a large number of Scopelus, Euphausiæ, Leucifer, Sagitta, fragments and bells of Diphyes and of Crystallodes, species of Schizopods, Doliolum, Salpæ, and some undetermined Penæids, with many Rhizopods, mainly specimens of Collozoum and of Acanthometra.

On the 16th of April, at 10 A. M., about 120 miles in a northwesterly direction from Acapulco, probable depth over 2,000 fathoms, the surface tow-net was hauled, the surface being quite smooth, the wind having gradually lessened from the time we left Acapulco. It contained very little beyond the usual Sagittæ, a small species of Salpa, a few Doliolum and Appendiculariæ, Calanus and other Copepods, Sergestes, Leucifer, and Euphausiæ, the same Mertensia we had found farther south, as well as the bells of a couple of species of Diphyes and of Crystallodes, apparently the same as those we obtained earlier in our cruise.

We then sent the Tanner tow-net to tow for fifteen minutes at a depth of 175 fathoms; it was closed by the messenger as usual. The lower part of the bag contained the same species we had caught in the surface tow-net; the number of individuals, however, was somewhat more abundant, and we obtained in addition Hyalea and Creseis, as well as Squilla larvæ.

On the 22d of April, about 75 miles southwest of Guaymas, in the middle of the Gulf of California, Station 3436, at a depth of 905 fathoms, the Tanner net was sent to tow at a depth of 800 fathoms. We towed fifteen minutes, when the messenger was sent to close the net. We must have shoaled our water, as the bottom net came up containing some mud. We brought up in the net Periphylla, and a new genus of Bougainvillia, allied to Rathkea, having eight chymiferous tubes, but only four clusters of tentacles.

The same day, Hy. Station 2637, at a depth of 773 fathoms, the Tanner net was again sent down to tow for twenty minutes, at a depth of 700 fathoms. The wire rope having fouled the detaching lines, the net came up open all the way to the surface. It must have towed very close to the bottom, as we brought up a fine specimen of Nettastoma, and two of the red deep-sea Caridids; but otherwise it contained nothing which we had not on some previous occasion obtained inside the 200 fathom limit from the surface. The proximity of land was apparent

from the presence of numbers of brachyuran larvæ, such as we had already found on the previous day in our surface haul. We obtained Periphylla, Stomobrachium, the new genus of Bougainvillia, bells of Diphyes and other Siphonophores, Doliolum, several species of Pteropods, Sagittæ, Ostracods, Copepods, Hyperiadæ, Schizopods, Penæids, and a few species of pelagic fishes.

On the 23d of April, a few hours before reaching Guaymas, we made one more attempt with the Tanner tow-net, Hy. Station 2638, at a depth of 622 fathoms, sending the net to be towed for about fifteen minutes, at a depth of from 500 to 570 fathoms. We found in this case in the bottom part of the net, which came up tightly closed, a Scopelus, a red Penæid, and a Hyalea, while the upper open part of the net contained the same surface species we had obtained in the surface tow-net on other occasions, such as Squilla larvæ, Ostracods, Doliolum, Euphausiæ, and Pteropods.

Our experience in the Gulf of California with the Tanner self-closing net would seem to indicate that in a comparatively closed sea, at a small distance from the land, there may be a mixture of the surface species with the free-swimming deep-sea bottom species, a condition of things which certainly does not exist at sea in deep water, in an oceanic basin at a great distance from shore, where the surface pelagic fauna only descends to a comparatively small depth, i. e. about 200 fathoms, the limits of the depth at which light and heat produce any considerable variation in the physical conditions of the water. The marked diminution in the number of species below 200 fathoms agrees fairly with the results of the "National" expedition.

The other experiments with the Tanner net, made in an oceanic basin on the way to Acapulco from the Galapagos, and to the Galapagos from Cape San Francisco, seem to prove conclusively that in the open sea, even when close to the land, the surface pelagic fauna does not descend far beyond a depth of 200 fathoms, and that there is no intermediate pelagic fauna living between that depth and the bottom, and that even the free-swimming bottom species do not rise to any great distance, as we found no trace of anything within 60 fathoms from the bottom where it had been fairly populated.

The first experiments of Chun regarding the distribution of the pelagic fauna were made in the Mediterranean, within a comparatively short distance from the shore, and in a closed basin having, as is well known, special physical conditions, its temperature to its greatest depths being considerably higher than the temperature of oceanic basins

at the limit of 200 fathoms, or thereabout, which we assume now to be near the limit of the bathymetrical range of the true oceanic pelagic fauna. At 200 fathoms in the Panamic district, the temperature was from 49° to 53°, while, as is well known, the temperature of the Mediterranean soon falls, already at 100 fathoms, to about 56°, a temperature which is continued to the bottom in this closed basin. Of course, if temperature is one of the factors affecting bathymetrical distribution, there is no reason except the absence of light which would prevent the surface pelagic fauna from finding conditions of temperature at the greatest depth similar to those which the surface fauna finds within the limit of 200 fathoms in an open oceanic basin.

My reasons for modifying the results obtained by Chun on his trip to the Canaries, I have given elsewhere, on page 23.

The results even of those who claim to have proved the existence of an intermediate fauna agree in showing that the number of species and the number of individuals greatly diminish near the 200 fathom limit, and that though my first experiment on the "Blake" proved the rapid diminution of the pelagic fauna at or below 150 fathoms, yet the azoic limit is a most variable one, judging from the later results of Chun and of Hensen, and from my own on the "Albatross." As long and as often as the experiments for determining the lower limits are confined to the Mediterranean or any closed or comparatively closed sea basin, or are carried on within close proximity to land, disturbing influences are at work which carry this limit far lower than we find it to be in an open ocean basin, far from land, where below 200 or 250 fathoms; and at 300 fathoms little or nothing has been found by us.

The Galapagos Islands.

As is well known, the Galapagos, when discovered by the Spaniards in the sixteenth century, were uninhabited, and remain so to-day; with the exception of the colony still maintained on Chatham Island by Mr. Cobos, all other attempts at settlement have failed.

Distant only a little over 500 miles from the Ecuadorian coast, they have often been visited by whalers, who landed on the islands for water, and for a supply of the large land turtles which made a pleasant variety in the sea fare of the whaling fleet frequenting these waters during the first half of this century.

The temporary occupation of some of the islands as a penal settlement by the Ecuadorian government followed the attempt at settling

Charles Island in 1831. After the disappearance of the convicts, they were occasionally visited by the orchilla traders, who cut down the scanty forests for the sake of obtaining more easily the valuable moss growing on the trees.

Dr. Theodor Wolf,[1] Ecuadorian State Geologist, has given a most interesting account of his visit to the islands, supplementing in many ways the account we owe to Darwin in his "Voyages of the Adventure and Beagle," and his "Volcanic Islands."

The Flora of the Galapagos.

Dr. Wolf has given a most characteristic description of the three belts of vegetation, which can be recognized on all the islands. (Plates XV.–XX.) The lower or more barren belt, characterized by its stunted vegetation, consisting near the beaches of salt-loving plants, probably all immigrants from the mainland, followed by grayish white apparently dry bushes, with small leaves and inconspicuous blossoms, the most common of which are a Verbena bush and a species of Acacia, with a large tree, the Palo Santo, which grows to a height of thirty feet. Where the lava fields seem to prevent the growth of any other plants, we find a tree-like Opuntia and a huge Cereus (Plate XX.). The last disappear as we rise, and on reaching the so called high plateau, the Acacia and Palo Santo increase in size, and the Verbena vanishes. When we reach the second belt, the lava blocks have become decomposed into a soft reddish earth by the action of the moisture from the prevailing trade winds, which blow refreshingly across from the south, and, carrying with them masses of moisture, have completely changed the aspect of the vegetation on the plateau (Plate XVII.), and of the weather side of the islands. The woods are green, composed of small trees, principally recalling the Polylepis of the Andes; they are open, their paths separated by grassy plots, till we gradually pass into the last and highest region, bare of trees, and covered by a rather coarse grass, which extends to the highest summits of the islands (Chatham, Charles, Indefatigable, and James).

Chatham Island is noteworthy for the special development of the lower volcanic barren region, and of the higher and grassy woody district, and, in addition, is distinguished by the barren volcanic tract which forms the eastern extremity of the island, on which, as we sailed by, we could scarcely distinguish any trace of vegetation, — the whole a mass of blocks of volcanic rock scattered between the numerous small volcanoes

[1] Ein Besuch der Galapagos Inseln, mit drei Kärtchen. Heidelberg, 1870.

so characteristic of that extremity of the island. Here and there grow, like huge candelabra, Cereus and Opuntias, forming clusters often over twenty feet in height, with thick branches; and close to the beach were clusters of small bushes and weeds, which probably represent, with the Opuntias growing between the lava blocks, the earliest flora which found a foothold in the Galapagos.

We may readily imagine, as pictured by Andersson, how, from the decomposition of a few Opuntias, a little humus formed the nucleus from which the seeds of other plants may have diverged, and gradually given rise, by a repetition of the process, to the soil supporting the present vegetation. Perhaps, if we contrast the so called characteristic species of the Galapagos, which find their analogues in the Central American district, we may be justified in looking upon the flora as a part of that district, an outlyer which has extended from the eastern centre to the westward, and yet regard the differences noticed in the flora as an expression of the special conditions due to the position, the climate, the age, and the soil of the islands, as contrasted with the corresponding conditions of the mainland.

As we ascend, we come upon thicker vegetation, not exactly of trees, but of large bushes, gradually passing into the region of small trees and of open fields, over which the mist hanging on the highest parts of the island spreads a slight moisture, and supplies the higher district with abundant vegetation and water over the fields which once were the home of the galapagos. And it may be that Chatham Island, as has been suggested by Andersson, being the one of the islands most exposed to the Humboldt Current and to the southeast trades, is the one which was first covered by South American plants.

On Charles Island, or Floreana, the vegetation is less luxuriant, the distance between the trees and bushes greater than on Chatham, and there seems to be a more definite limitation of the districts occupied by each group of plants (Plates XX., XXI.); and on the shore of Black Beach [1] we come at once upon a number of plants which are quite com-

[1] "We anchored in Black Beach Road in eleven fathoms, sand. This anchorage is an open bay, but being on the west or lee side of Charles Island affords a good shelter from the trades, which blow most of the year. It is the seaport of what was at one time a flourishing settlement, now abandoned, and derives its name from a short stretch of black lava sand beach lying at the head of the bay, between low cliffs of dark lava rock. [See Plates XVIII., XIX.] At the time of our visit [1888] great numbers of cattle, horses, mules, donkeys, sheep, and hogs were running wild. The buildings were fallen to ruin, but there was a plentiful supply of fruit on the trees, from which we procured many bushels of oranges and limes, a

mon on the coast of Panama and Guayaquil. In the upper regions of Charles the vegetation is more luxuriant, the open fields forming quite extensive undulating plains.

The general appearance of the vegetation of Indefatigable is much the same in its general subdivisions as that of Chatham and Charles.

As Andersson says,[1] with the exception of Australia and some of the islands of that faunal district, no land perhaps possesses so many characteristic plants as the Galapagos, as more than half of the plants thus far known are peculiar to the Galapagos, and of these only a very small portion are common to all or a majority of the islands.

Part of the vegetation has come from the West Indies and Panama, or is allied to that of Southern California, of Mexico, of Southern Colombia, and of the high plains of the Western Andes, perhaps as far south even as Chili. No one has better than Hooker[2] given the probable course which was followed by the plants which have reached the Galapagos from these different regions, and which in the course of centuries have become more or less modified, so as to bear but a distant resemblance to the plants now growing in the very regions from which they came.

The course of the currents along the Mexican and the Central and South American coasts clearly indicate to us the sources from which the fauna and flora of the volcanic group of the Galapagos has derived its origin. The distance from the coast of Ecuador (Galera Point and Cape San Francisco) is in a direct line not much over 500 miles, and that from the Costa Rica coast but a little over 600 miles, and the bottom must be for its whole distance strewn thickly with vegetable matter, which, as I have already stated, came up in great masses in almost every haul of the trawl. This was especially noteworthy in the line from the mainland to Cocos Island, and certainly offers a very practical object lesson regarding the manner in which that island must have received its vegetable products. It is only about 275 miles from the mainland, and its flora, so similar to that of the adjacent coast, tells its own story. Malpelo, on the contrary, which is an inaccessible rock with vertical sides (Plate XIV., and destitute of any soil formed from the disintegration of the rocks, has remained comparatively barren, in spite of its closer proximity to the mainland.

pleasant addition to our monotonous fare. The distance from the landing to the first improvements was about three miles, over what had been a good wagon road."— Tanner's Report.

[1] Linnæa, XXXI., 1861-62, p. 595.

[2] Hooker, J. D., Linn. Soc. Trans., 1851, Vol. XX. p. 163.

The velocity of the currents in the Panamic district is very great, sometimes as much as seventy-five miles a day, so that seeds, fruits, masses of vegetation harboring small reptiles, or even large ones, as well as other terrestrial animals, need not be afloat long before they might safely be landed on the shores of the Galapagos. Its flora, as is well known, is eminently American, while its fauna at every point discloses its affinity to the Mexican, Central or South American, and even West Indian types, from which it has probably originated; the last indicating, as well as so many of the marine types collected during this expedition, the close connection that once existed between the Panamic region and the Caribbean and Gulf of Mexico, — a connection once extending, probably, through deep and wide passages all the way from the northern extremity of Colombia, the Isthmus of Panama, Costa Rica, and as far north as the Isthmus of Tehuantepec.

Having followed in the footsteps of Dr. Wolf on Charles Island, I cannot do better than to refer to his accurate description of that island, to which I shall add my own observations, as well as those on Chatham and on Duncan, which the "Albatross" also visited. To attempt the ascent of any one of the islands directly from the beaches near the anchorages is a most difficult task. (See Plates XVIII., XIX., XX.) The lower slopes, although rising very gradually, yet are so covered with stunted vegetation, growing between the crowded angular blocks of lava (Plate XVI.), that progress is very slow. One has to pick one's way over the lower lava fields which extend unbroken to a height of nearly 800 or 900 feet from the level of the sea before they begin to show the effect of the disintegrating action of the moisture of the higher regions of the islands.[1] The general aspect of this higher plateau, both on Charles and Chatham (Plate XVII.), is much varied, a large number of small, isolated rounded peaks rising from the general level to a height of 200 to 400 feet, and culminating towards the central mass in the highest points of the islands. On the weather side the moist region reaches to a lower level than on the lee side, and on both Chatham and Charles this year quite heavy rains extended to the very level of the sea, a somewhat unusual state of things. I was informed by Mr. Cobos

[1] Although Darwin, in his account of the visit of the Beagle to Charles Island, in the last part of September, 1835, after commenting on the similarity, in all the islands, of the first part of the road leading from the sea inland, says: "Higher up, the road gradually became greener, and immediately we had crossed the ridge of the island our bodies were cooled by the fine southerly trade wind, and our senses refreshed by the sight of a green and thriving vegetation."

that rains do not usually extend uniformly to so low a level even during the rainy season,[1] being limited to the higher levels above 500 or 600 feet, and to the higher plateaus, where even during the dry season, the fall and early winter, there are frequent falls of mist.

Arriving as we did at the Galapagos at the beginning of a remarkably early rainy season, I could not help contrasting the green appearance of the slopes of the islands, covered as they were by a comparatively thick growth of bushes, shrubs, and trees, with the description given of them by Darwin, who represents them in the height of the dry season as the supreme expression of desolation and barrenness.[2] Of course, here and there were extensive tracts on the sea-shore where there was nothing to be seen but blocks of volcanic ashes, with an occasional cactus standing in bold relief, or a series of mud volcanoes, or a huge black field of volcanic rocks, an ancient flow from some crater to the sea; but as a rule the larger islands presented wide areas of rich, fertile soil, suitable for cultivation. The experiments at Charles Island, where there is a deserted plantation, and at Chatham Island, where Mr. Cobos has under successful cultivation a large plantation, producing sugar, coffee, and all the tropical fruits, as well as extensive tracts on which his herds of cattle, sheep, and donkeys roam towards the higher central parts of the island, show the fertility of these islands. They are indeed as favorably situated for cultivation as the Sandwich Islands or Mauritius, and there is no reason why plantations, if properly managed, should not in the near future yield to their owners as large returns as they do on those islands.

From the very shore, after passing the coral sand beach (Plate XV.), the road leading from Wreck Bay,[3] Chatham Island, to the hacienda of

[1] Yet the experience of Captain Tanner, in 1888, would seem to indicate that even at the level of the sea heavy rains may occur. He says: "The weather was partly overcast when we left our anchorage at Albemarle, but we thought little of it, supposing it to be one of the short passing squalls so frequent during the rainy season. When we reached the vicinity of Cape Berkeley, however, the rain poured down in torrents for several hours, and it became so thick that we were obliged to stop the engines until the weight of it passed, when we continued our course, anchoring in James Bay at 1.30 P. M. in six fathoms, white sand."

[2] Darwin says of his first landing on Chatham Island: "Nothing could be less inviting than the first appearance. A broken field of black basaltic lava is everywhere covered by a stunted brushwood, which shows little signs of life." And speaking of the plants, he says: "I succeeded in getting only ten kinds; and such wretched-looking little weeds would have better become an arctic than an equatorial flora."

[3] With the consent of the Commissioner of Fisheries, I have added to my own account of the Galapagos extracts from the excellent reports of Captain Tanner

Mr. Cobos was almost impassable from the mud, and on our way up in the last of March, we could not fail to see the traces of the damage done to the road by the washing of the heavy rains which had fallen during February and March, and which were falling during a part of the days we spent on the island. The higher part of the island (Plate XVII.), where the plantations of Mr. Cobos are placed, are well watered by irrigation, and the supply, brought from about five miles, is ample for a large extent of territory. But although there is an abundance of water in the central parts of the islands, we saw nowhere, as on Cocos Island, such an abundance of water running into the sea. The contrast between Cocos and the Galapagos is most striking. Although not very distant, yet the former is in the rainy belt, and its luxuriant vegetation, extending from the summit close to the water's edge (Plate XIII.), is in marked contrast to the distribution of vegetation on the Galapagos. Cocos Island is reeking with moisture, and its rocky faces, matted with ferns and covered with groves of palms towering above the other trees, seem to have nothing in common with the scanty vegetation characteristic of the lowest slopes of the Galapagos.

made to the U. S. Fish Commissioner relating to his visit to the islands in the "Albatross" during the early part of 1888, while on the way from New York to San Francisco: "This [Wreck Bay] is the seaport of the Hacienda del Progreso, a plantation located on the highlands in the interior of the island, about five miles distant, and connected with the coast by a good wagon road. The bay is surrounded by low land covered with bushes and small trees, and a smooth steep sand beach affords convenient landing. The land begins to rise a few hundred yards from the beach, and the ascent is constant until the hacienda is reached, at an elevation of about 900 feet above the level of the sea. The low lands of Chatham, in common with those of all the islands of the archipelago, are entirely without living water, and in the dry season present a most barren and desolate appearance. All this is changed, however, during the rainy season, which usually begins about the 1st of April, and continues until the last of June. It began in February this year, and in consequence everything was fresh and green, the general aspect being decidedly tropical. In company with Señor Cobos and son we rode over a portion of the estate, where we saw great fields of sugar-cane, sweet potatoes, and other tropical and semi-tropical products, growing side by side. A young coffee plantation gave promise of future profit, and oranges, lemons, and limes were growing in profusion. Large herds of cattle were seen feeding in excellent pastures, enclosed with iron fences, hedges, or the favorite broad deep ditch, the proprietor estimating the number of cattle on the island at 20,000. Horses, mules, asses, sheep, and hogs were seen in large numbers, more than sufficient for all purposes of the plantation. Water was procured from a large spring and carried to the settlement by ditches, which could be seen winding around the hills. Chatham Island, and in fact all the islands of the archipelago, are of recent volcanic origin, the only arable land being in the elevated basins of the craters. Here, on the principal cone near the centre of the island, we found the Hacienda del Progreso."

Topography of the Galapagos.

As seen from the sea from the southeast, distant about ten miles, the western half of Chatham Island forms its principal and highest part. It rises more rapidly from its western extremity at Wreck Point to a height of 2,490 feet, as marked on the Admiralty charts. This summit is separated by a high land from the next highest point, which reaches an elevation of nearly 2,000 feet. From here the western mass gradually falls with gentle slopes toward the east, and is separated by a low valley from the central mass, slightly undulating and with two nearly equal summits, which reach less than one third the height of the western half. This in its turn is separated from the eastern extremity of the island, which is somewhat higher than the central mass. The southern slopes of the western mass of the island are covered by numerous small craters, and here and there its even outline as seen against the sky is interrupted by the sharp line of a smaller crater. Along the southern shore on the eastern half of the island there are a large number of the so called tuff craters, readily distinguished from the other craters, even at the distance at which we saw them, by their reddish color. They form a prominent line of well defined low, sharp cones, with more or less perfect craters.

Hood Island we did not visit. Captain Tanner, who passed a day on the island in 1888, says: "It is low compared with others of the group, its surface being covered with masses of broken lava rock. A little soil has formed between the blocks, in which bushes of various kinds find root, and during the season of rains lend a rich green hue to the otherwise barren surface. It is wholly devoid of fresh water during the dry season, and has no commercial value. Gardner's Bay is a good anchorage in the fine weather that usually prevails."

Indefatigable Island is perhaps the one of the Galapagos which best shows the mode of their formation. It forms a single mass, rising gently on all sides toward the great central plateau; its sides are comparatively little broken by lateral craters; the central plateau is surrounded by a series of rounded elevations, the remnants of the rim of the old crater. According to Mr. Cobos, after passing the lower line of the lava boulders one reaches, at about the same elevation as on Chatham and Charles, the plateau region, where the lava has become decomposed into a most fertile soil, and for the size of the island its area fit for cultivation is quite extensive. The general character of the lower slopes, which reach to the water's edge, do not differ from those of the

other islands we visited. Innumerable spits, composed of huge lava blocks running into the sea and separated by small coral rock beaches, similar to those I have described at Wreck Bay on Chatham Island, at Black Beach on Charles Island, and on Duncan Island. Conway Bay itself, where we anchored for the night, on Indefatigable Island, is a fine example of one of the coral rock beaches so characteristic of the Galapagos. Off to the north of Conway Bay are the Guy Fawkes Islands, one of the old craters of which is still barely visible. The craters of the other island appear to have been sloughed off on their southern face.

Captain Tanner, in the report of his visit to the Galapagos in 1888, says: "Indefatigable Island is circular in form and about twenty miles in diameter, with a central cone, in the basin of which lies a vast tract of arable, well watered land, capable of growing all the tropical and semi-tropical products in great perfection. Its natural resources are greater than those of any other island in the group, yet it is uninhabited and wholly undeveloped. The low lands are devoid of water, and, like the other islands, barren and desolate during the dry season, the rain only bringing life to the bushes and stunted trees, which find a precarious existence among the lava boulders and scoria."

Narborough Island, as stated by Captain Tanner, "presented in the distance (as seen from the weather side) an unbroken covering of rich green foliage to the very summit of its central peak, 3,720 feet above the sea, and, on nearer approach, a fringe of luxuriant mangroves, bordering the eastern shore and the margin of a small bay or lagoon, added fresh charm to the view. As we steamed through the narrows between Narborough and Albemarle Islands the contrast of a rich and abundant vegetation on the one hand, and utter barrenness and desolation on the other, was very striking."

Narborough, which on this trip we only saw from a distance, towering behind Albemarle, may show the character of the building up of the separate islands better even than Indefatigable, for its single cone, rising to a height of over 3,700 feet, still possesses a well preserved crater.

The composite nature of some of the islands is best seen on Albemarle. It rises to a greater height than any of the other islands (4,700 feet), and, as we saw it from the sea, the lower slopes of its five highest cones passed one into the other at various elevations. The three northern ones were separated by a comparatively low isthmus from the two southern peaks, which form the southern half of the island, the general trend of which is nearly at right angles to that of the northern craters.

We only saw Albemarle in the distance, and the following account of the island is taken from Captain Tanner's report :—

"Albemarle Island is by far the largest of the archipelago, but is uninhabited, and has no present commercial value except for its orchilla, which grows on bushes and trees, and has slight resemblance to Florida moss. It is used for making purple dye, and commands a high price in the European markets. The highest point on the island is within three or four miles of the southern extremity, and reaches an elevation of 4,700 feet. A rich green foliage covered the rugged surface of huge lava boulders to the very summit. Further to the northward, and all along the west coast as far as Tagus Cove, the land was comparatively low, and presented a striking resemblance to a burnt district dotted with numerous small volcanic cones. The general aspect was a reddish brown, but it was varied by occasional pyramids, symmetrical in form, and of lighter color, resembling artificial mounds of sand and mud which had had barely time to dry. The line of demarcation between the rich carpet of foliage and utter desolation of the barren district was so regular and well defined that it was difficult to realize that it was Nature's handiwork. The watering place marked on the chart was perfectly dry, and we learned from Mr. Cobos that it was only during the latter part of the rainy season that water could be found. There were patches of green near the northern end of Albemarle Island, but the general aspect was barren and desolate."

James Island as seen from Duncan rises rapidly on its western edge, culminates in a high crest, broken by numerous projecting rounded summits forming the central ridge of the island, and slopes rather gradually towards its eastern extremity, where there are a number of small cones and craters similar to those of the southeastern face of Chatham Island.

Darwin passed a week on James Island. He paid a visit to its upper regions, and reached an altitude of nearly 2,000 feet. He speaks of "the upper region being kept damp from the moisture of the condensed clouds, and supporting a green and flourishing vegetation," although he found the lower region covered by nearly leafless bushes.

James Bay, where the "Albatross" anchored in 1888, is, as Captain Tanner says in his Report to the Fish Commissioner, "on the west end of James Island, which protects it from the prevailing winds, the swell being partially broken by projecting points and small islands. It is a good anchorage with easterly winds, and may be recognized by the following landmarks. Albany Island is conspicuous, being lighter in color than

its surroundings, and abreast of it are bold lava cliffs, which extend to a short stretch of white sand beach at the bottom of the bay. The southern extremity is marked by a point having a double peak, from which extends a barren lava-colored belt, resembling that described on Albemarle Island. Small salt lagoons lie just back of the sand beach. The watering place mentioned is on a point nearly abreast of Albany Island, and during the latter part of the rainy season furnishes a good supply, but at other times the flow is either very small, or fails altogether. The supply is so limited and uncertain that the orchilla pickers who visit the island periodically do not depend upon it. The general aspect north and east of the bay was fresh and green, and a fringe of mangroves surrounding the lagoons gave that portion of the bay a particularly attractive appearance, while to the southward was a barren waste."

The landing at Duncan is in a boat cove, protected by a small island. The bottom is covered by coral sand, formed of fragments of Pocillopora. A number of seals evidently had chosen this spot as their favorite haunt, and on their way to a small plateau a little higher up, which they evidently frequented, had in some places worn the shore rocks perfectly smooth. There were perhaps twenty or thirty seals here, who must have found an abundant supply of fish, judging from the number we saw around the ship while she lay at anchor off the island. They must have been quite common on the Galapagos, and have been noted as occurring on Hood, Charles, Chatham, James, and Jarvis. Both albatross and penguin appear to have been known on the islands, the latter a species characteristic of the group.[1]

The photograph of a part of the eastern slope of Duncan Island (Plate XXII.), opposite our anchorage, will give a better idea of the character of its shores and its vegetation than any more lengthy description I could give. Duncan Island rises quite abruptly on all sides from the sea, and with the exception of a small plateau on its southern extremity well towards the summit, and of a slight depression between the highest point and the northern end, presents a nearly regular conical outline as seen from the sea.

Opposite our anchorage on Duncan Island we found a number of

[1] I am informed by Captain C. A. M. Taber of New Bedford, who twice visited the Galapagos, the first time as early as 1843, that he discovered an albatross rookery on the weather side of Hood's Island, and on his second visit he made a number of observations on the seal rookeries of various islands, which he mentioned in a late number of "Science," May 27, 1891.

the aquatic Amblyrhynchus crawling about upon the lava rocks, close to the water's edge. Neither at Chatham, Charles, nor Duncan did I see any specimens of the terrestrial species.

Captain Tanner in speaking of the anchorage off Duncan Island says: "We anchored in fifteen fathoms in an open bay on the northeast side of Duncan Island. We were off a conspicuous gorge in the mountain side, and about two hundred yards to the southward of a small islet which lay directly in front of it, and about fifty yards from the shore. Its surface was covered with bushes and other vegetation, which distinguishes it from rocks farther to the southward. There was an excellent landing place for boats inside of the islet. The general appearance of Duncan Island was green, bushes and cactus being distributed over its surface. There is no living water on the island, yet it is a favorite resort for the celebrated galapagos."

The northern and northeastern islands of the group are far more barren than the central and southern. This is natural, as neither Bindloe nor Abingdon is high enough to reach the altitude where in the larger islands we find a comparatively moist and cool climate, and where the high plateau is fairly fertile and capable of cultivation. On the Admiralty charts, according to the survey of Fitzroy, Bindloe is not more than 800 feet, and Abingdon has only a small area above 1,000 feet. So that, as far as we could judge while sailing by these islands, they hold an intermediate position as regards their appearance between such islands as Duncan and Wenman, and the larger, higher, and more fertile islands Chatham and Charles. Tower Island we did not sight. Seen from the ship, the geological structure of Abingdon and of Bindloe did not differ from that of the other islands of the group. Bindloe as seen from the west resembles Chatham somewhat, but is more broken by craters, and a large part of the southern face of the island is covered by a huge flow of black lava rocks, standing out in bold relief against the green slopes surrounding it on every side.

Bindloe, although so much broken up by its many craters, forms only a single mass, the craters being arranged in a somewhat irregular ring around the plateau which constitutes its centre.

The eastern face of Wenman is a perpendicular cliff. The top of the island is covered with a thin coating of green, consisting of tall grass, and of a scant vegetation, and is evidently more barren than Duncan Island. Its eastern face seems to have been sloughed off.

Culpepper Island we passed in the dark.

The Fauna of the Galapagos.

In addition to a large number of oceanic birds shot by Mr. Townsend during the cruise, he also made an important collection of birds from Chatham and Charles Islands, considering the short time we were there. On our way up to the hacienda of Mr. Cobos, we had our first experience of the great tameness of the birds. They did not seem to be in the least affected by our presence, and while we halted some of them rested on the mules' hind quarters, and even on the shoulders and hats of some members of the party. Our experience on Charles Island was similar. On all sides the finches and thrushes paid no attention to us, and a number could readily have been caught with a butterfly net, or even a hat. Yet there has been some population on Chatham Island for a number of years, and Charles Island has of late been rarely visited. I need only refer to Darwin's account of the tameness of birds, in his "Voyages of the Adventure and Beagle," Vol. III. p. 475.

As regards the fauna of the Galapagos, I may mention having seen a bat, which I was told by Mr. Cobos he had noticed on Chatham Island only for the last six or seven years. Dr. Wolf mentions them in 1875, and I hear from Dr. Baur that he has collected some specimens. It is interesting to remember that since Darwin's visit, in 1835, a number of domesticated animals have become wild, and have greatly multiplied since the abandonment of the settlements on Charles Island. We have wild cattle on Chatham, on Charles, on James, and on Indefatigable; also, wild donkeys, hogs, sheep, goats, cats, dogs, and the common fowl.

I collected insects on Chatham, Charles, and Duncan, and was amazed at the poverty of the catch. Of course a prolonged stay would undoubtedly bring to light many interesting things; but of the few species of Lepidoptera, an Argynnis, a Colias, a Eudamus, and a Lycæna seemed to be the most characteristic, and were found on all these islands. A few Noctuidæ, and only few species of Diptera, of Hymenoptera, or of Neuroptera, though one of the species of the Libellulidæ was very abundant on Chatham, two species of Acridium, a large one inland and a smaller species in the lower levels, and two or three species of Coleoptera, among which was a Carabus, were all I found. My short experience seemed not to differ materially from that of Dr. Wolf, whose entomological collections were most meagre, although he collected in the dry season. I was greatly struck with the vast number of caterpillars, but of a few species only, of Noctuidæ, Geometridæ, and Sphingidæ, which covered the

grasses and bushes on Charles and Chatham Islands, and must have supplied the insectivorous birds with abundant food.

A few reptiles were collected at the Galapagos, Cocos Island, and Malpelo.

The only tortoise we obtained was found on Duncan Island by Mr. Townsend; we kept it on board the "Albatross" as far as Guaymas, and from there it was shipped to Washington, where it arrived safely.

The well worn tortoise tracks which Darwin saw on landing at Chatham Island, leading to the springs, which are situated on the larger islands towards the central parts and at a considerable elevation, are still quite marked on Charles Island. I saw no trace of them either on Chatham or on Duncan, on the parts of the islands which I examined. On Chatham, the tortoises, I was told by Mr. Cobos, have long since disappeared. According to Darwin, "it is said that formerly single vessels have taken away as many as seven hundred of these animals," so that the disappearance of the turtles is not astonishing; and they and the terrestrial Amblyrhynchus, which also serves as food, have become comparatively rare. We also collected at Duncan Island a few specimens of the aquatic Amblyrhynchus.

Sharks are very abundant throughout the waters of the Galapagos, and they, as well as the strong currents sweeping through the passages which separate the islands, may play an important part in checking the migration of animals from one island to another. We saw small sharks in great numbers at all our anchorages. Captain Tanner says that, in 1888, "the anchorage at Wreck Bay was infested with small sharks, which were taken by dozens until the fishermen tired of the sport."

A few specimens of rocks were also brought together from the different islands we visited, and such plants collected as it was possible to get during our short stay on shore.

The Coral Sand Beaches of the Galapagos.

I obtained from Mr. Cobos a piece of the so called sandstone said to occur on Indefatigable Island, and which of course I was most anxious to see, as the occurrence of true sandstone would have put quite a different face on the geological history of the Galapagos from the one usually received. This I found to be nothing but coral rock limestone, either a breccia or slightly oölitic, identical with the formation found back of the beach at Wreck Bay on Chatham Island. I found there an old coral rock beach, extending on the flat behind the present beach, composed

entirely of fragments of corals, of mollusks, and other invertebrates, cemented together into a moderately compact oölitic limestone, which when discolored, as it often is, and turned gray, might readily be mistaken for sandstone. This coral rock is covered by just such a thin, ringing coating of limestone as characterizes the modern reef rock of other localities. On nearly all the islands there are a number of sandy beaches made up of decomposed fragments of corals and other invertebrates, and cemented together at or beyond high-water mark into the modern reef rock I have described. The coral is mainly made up of fragments of Pocillopora, which is found covering more or less extensive patches off these coral sand beaches, but which, as is well known, never forms true coral reefs in the Panamic district. The only true coral reef belonging to this district is that of Clipperton Island (if we can trust the Admiralty charts), situated about 700 miles to the southwest of Acapulco. But neither at Cocos Island, nor at the Galapagos, nor anywhere in the Panamic district, do we find true coral reefs, — nothing but isolated patches of reef-building coral. The absence of coral reefs in this district has of course already been noted by other naturalists, who have been struck by this feature in an equatorial region. Dana has ascribed it to the lower temperature of the water due to the action of the Humboldt Current coming from the south, pouring into the Bay of Panama, and then flowing westward with the colder northerly current running along the west coast of Mexico and Central America. From the investigations made this year by the "Albatross," I am more inclined to assume that the true cause of the absence of coral reefs on the west coast of Central America is due to the immense amount of silt which is brought down the hill and mountain sides every rainy season, and which simply covers the floor of the ocean to a very considerable distance from the land, the terrigenous deposits being found by us even on the line from the Galapagos to Acapulco, at the most distant point from the shore to the side or extremities of our line. The mud in Panama Bay to the hundred fathom line is something extraordinary, and its influence on the growth of coral reefs is undoubtedly greatly increased from the large amount of decomposed vegetable matter which is mixed with the terrigenous deposits.

The Origin of the Fauna and Flora of the Galapagos Islands.

In an article on "The Origin of the Galapagos Islands," in the American Naturalist, (March and April, 1891,) Dr. Baur has expressed views on the origin of the fauna and flora of the Galapagos entirely at variance

with what is known of their geological structure. He speaks of the Galapagos as being connected with the mainland by the 4,000 meter line. The ease with which such connections are made on a chart requires no serious discussion. Then he adds, "This [the connection of the Galapagos with South America] is an important fact; all the older maps showed the Galapagos separated from Central America." (!)

The islands of Duncan and Gallego, which are said to have existed between Clipperton and the Galapagos, he assumes to have disappeared. Their existence does not rest on any better basis than that of so many islands and shoals constantly reported by inexperienced or hasty navigators. Take the Rivadeneyra Shoal, — on which the "Albatross" has paid out over 1,000 fathoms, — which has been twice reported of late years, and is either a rip or an effect of light.

The connection of Vancouver and the Alaska Islands with the mainland, or that of the Santa Barbara Islands, Guadalupe, and other Californian islands, has nothing to do with the question of the former connection of the Galapagos with the South American continent. Each case must be judged by itself. Baur also brings up the case of the Tres Marias, which consist of stratified rocks and are close to the Mexican coast, separated from it by a flat of not more than thirty fathoms, and speaks of them as on the same bank as Socorro and the Revilla Gigedo Islands. This seems to be taking a good deal of poetical license with our present knowledge, and especially to bring them up as an argument from analogy that the Galapagos have been a part of South America because they may have been and are within the 4,000 meter line. One would imagine from Dr. Baur's argument that the islands of Felice and Juan Fernandez are closely connected with and due south of the Galapagos. Surely so much is known of the habits of the seals and of the albatross that we need not look upon their existence on the islands as proving any land connection between the southern points where they are known to breed, and the Galapagos, where they also have colonized. Dr. Baur also mentions the case of the Sandwich Islands as having originated by subsidence. No more unfortunate suggestion could have been made regarding their origin. All we know of their geology seems to show that the different islands have been gradually built up around a central nucleus by successive eruptions, much in the same way that the Galapagos were. It seems hardly worth while, on the basis of the assumption of Dr. Baur, to renew speculations on the theory of the permanence of the Pacific Ocean basin. After Dr. Baur has completed his examination of the Galapagos, and has given us the additional soundings

leading to different views from those based upon our present knowledge, it will be time to discuss the matter. When Dr. Baur says, "It would appear that the whole west coast of America has undergone subsidence," he is making a statement which is absolutely without foundation. On the contrary, all that we know of the geology of the west coast of Mexico, of Central America, and of South America, shows that their shores have been rising to a very great elevation as far south as the southern part of Chili. Dr. Baur need only refer to Darwin's "Geological Researches," and to the statements of the geologists who have examined the geology of Central America, to satisfy himself on that point.

What has taken place north of the Gulf of California need not detain us. Why should not Cocos Island and Malpelo come within the same influences of subsidence? Some of the causes which Dr. Baur applies to the Galapagos to explain their present state have given the one its luxuriant vegetation, and have kept the other barren, and they are still plainly visible on the most cursory examination. The vegetation of the rainless belt along the coast of South America presents the same peculiarities and the same contrasts as that of the Galapagos and Cocos; given an absence of rain, and what can be more desolate than the region around Payta, the greater part of the coast of Peru, and northern Chili? Yet where do we find more brilliant verdure than along the river beds of the same region, or in districts which can be irrigated? Absence of rain and moisture in the equatorial regions apparently produces as great a diminution in the size of the constituents of a flora as the excessive cold of an arctic climate or a high altitude.

It seems far more natural to us to appeal, as we have done, to the agency of the trade winds and currents to account for the origin of the fauna and flora of these interesting islands. We are thus not called upon to accept a theory of extensive subsidence in an area where all the geological indications are those of elevation, especially when the proof of this subsidence is based on no better evidence than the so called alpine character of parts of its flora, and upon the presumed former connection of the Galapagos Islands with the Central American continent. The alpine features of the flora we have attempted to explain by its similarity to that of the adjoining rainless belt of South America, and we deny the existence of a former connection of these volcanic islands with the mainland, separated as they are now by a plain of nearly 2,000 fathoms in depth.

While slowly steaming through the archipelago from island to island,

we had an excellent opportunity of studying the natural features of these islands, and also as we passed their shores or were dredging within a moderate distance. As far as a cursory examination like ours could prove anything regarding the nature of the geological structure of the islands, our observations fully agree with those of Darwin and of Wolf, that this group presents one of the best examples of true volcanic islands.

The majority of the islands are evidently formed around a central crater or centre of elevation. They have increased in size and in height from successive lava flows. There is nothing to show that the separate islands are entirely the result of the disintegration of a larger volcanic chain, though of course a certain amount of denudation and submarine erosion has undoubtedly taken place, as is readily seen on the slopes of the islands and on examination of the soundings between them. Neither do we find any indications either of elevation or of subsidence of any part of the area of the Galapagos district which would affect their topography, and, as Wolf maintains, we can still less explain their formation by a separation in former periods from the South American continent. On the contrary, every part of their structure seems to prove that the islands have been slowly formed by submarine eruptions at first, and subsequently by similar accretions at the level of the sea, until finally some of the islands have reached an elevation of over 3,000 feet. During this process of growth some of the islands have become joined together, as for instance Albemarle, which is probably composed of three islands originally independent, and also the eastern and western parts of Chatham, which were surely once two separate islands, and are now connected only by a low isthmus.

The volcanic activity of some of the islands has continued to comparatively very recent times. I am informed by Mr. Cobos that smoke has been seen to issue from Narborough as late as 1836, and it is well known that Captain Collet was driven from Tagus Cove by the heat due to an eruption on the neighboring Narborough. It is quite probable that the age of the Galapagos does not reach beyond the earliest tertiary period, and many parts have undoubtedly not been formed before the present epoch, so that the time is geologically short during which so many animals and plants peculiar to the islands have developed from their South American, their Central American, their Mexican, or their West Indian ancestors.

Wolf has already called attention to the fact that the petrographic character of the Galapagos volcanoes is different from that of the vol-

canoes of the mainland, the latter consisting of trachytic and andesite material, while the former are made up of basaltic rocks. The specimens of volcanic rocks which I collected at Chatham Island, on Charles, and on Duncan Island, were all basaltic.

Wolf, whose acquaintance with the flora of the high Andes appears to be very extensive, was struck with the Andean character of the Compositæ, and with the analogy of a species of Polylepis and other trees with those forms that in the high Andes[1] make small forests, reaching to an altitude of 13,000 feet. He found also a remarkable similarity in the mosses and ferns with those of the Quito district, and some of the species he even considers as identical.[2] As he well says: "Es ist kein Zweifel, dass die Vegetation, trotz ihrer Eigenthümlichkeiten, im Ganzen einen südamerikanischen Typus besitzt, sowohl nach den Gattungen als nach dem äussern Habitus; wodurch sie sich aber auf den ersten Blick von der Flora des Festlandes auch dem Nicht-Botaniker unterscheidet, ist die Kleinheit der Blattorgane[3] die Abwesenheit schöner Blüthen, die Seltenheit der epiphytischen Gewächse, und das Fehlen der Lianen oder Schlingpflanzen." We miss all the wealth of the tropical forests, which is so striking in the equatorial zone of Central and South America.

The Deep-Sea Fauna of the Panamic District.

As a striking result of the character of the deep-sea fauna of the Panamic district, we found, in the first place, a great many of my old West Indian friends. In nearly all the groups of marine forms among

[1] Is it not perhaps more natural to compare the vegetation of the lower belt of the Galapagos to that of the rainless belt extending along the coast of South America from Ecuador southward? The stunted character of the vegetation of the rainless belt is as marked a feature of that district as it is of the Alpine regions.

[2] Hooker, while discussing (Trans. Lin. Soc., 1851, Vol. XX. p. 163) the affinities of the flora of the Galapagos and its origin, lays great stress upon the action of currents coming north from the Guyaquil River, and those flowing westward from the Bay of Panama, as agents for the distribution of South and Central American plants. Speaking of the affinities of the plants of the Galapagos, he says: "The new species being for the most part allied to plants of the cooler parts of America, or the uplands of the tropical latitudes. The more peculiar are the same as abound chiefly in the hot and damper regions, as the West Indian Islands and the shores of the Gulf of Mexico."

[3] As Darwin says, the bush which from its minute brown leaves chiefly gives the leafless appearance to the brushwood is one of the Euphorbiaceæ, and an acacia and a cactus are quite common in some parts, while in the upper regions of the islands the ferns and coarse grasses are abundant.

the Fishes, Crustacea, Worms, Mollusks, Echinoderms, and Polyps, we brought up familiar West Indian types or east coast forms, together with quite a number of forms whose wide geographical distribution was already known, and is now extended to the Eastern Pacific. This was naturally to be expected from the fact that the district we explored is practically a new field, nothing having been done except what the "Albatross" herself has accomplished along the west coast of North and South America. The "Challenger," as will be remembered, came from Japan to the Sandwich Islands, and from there south across to Juan Fernandez, leaving, as it were, a huge field of which we attacked the middle wedge. As far as we can judge at present, it seems very evident that, even in deep water, there is on the west coast of Central America a considerable fauna which finds its parallel in the West Indies, and recalls later Cretaceous times, when the Caribbean Sea was practically a bay of the Pacific, — a deep-sea fauna showing relationship on the one side to Atlantic and West Indian types, and on the other pointing to the eastward extension of western Pacific types of wide geographical range, which mix with the strictly deep-sea Panamic ones. The western and eastern Pacific fauna, while as a whole presenting very marked features in common, yet also present striking differences. The vast extent of territory over which some of the marine types extend, through all the tropical part of the Pacific, may readily be explained from the course of the great western Equatorial Current and the eastern counter currrent, which cannot fail to act as general distributers in space for the extension of a vast number of marine Vertebrates and Invertebrates. A similar extensive geographical range from north to south has also been observed in the distribution of some of the Mollusks, Echini, and Starfishes, which extend all the way from the southern extremity of South America to the Panamic region. The course of the northerly current setting along the west coast of South America must of course act as a distributer of the marine fauna of that region. There are, indeed, a number of genera in the deep water, and to some extent also in the shallower depths, which show far greater affinity with the Pacific than with the Atlantic fauna. Of course, further explorations may show that some of these genera are simply genera of a wider geographical distribution; but I think a sufficiently large proportion of the deep-sea fauna will still attest the former connection of the Pacific and the Atlantic.

In the first part of our cruise I was somewhat disappointed in the richness of the deep-sea fauna in the Panamic district. It certainly does not

compare with that of the West Indian side, or that off the eastern coast of the United States. I have little doubt that this comparative poverty is due to the absence of a great oceanic current like the Gulf Stream, bringing with it on its surface a large amount of food which serves to supply the deep-sea fauna along its course.

The same comparative poverty of animal life also characterized our second line of explorations. After we reached Galera Point, we began our line across the Humboldt Current, which was to give us a fair idea of the fauna of that part of the coast as far as the southern face of the Galapagos. With the exception of three good casts, the trawling on that part of the sea bottom proved comparatively poor, nor did the sea face of the southern slope of the Galapagos give us anything like the rich fauna I had expected. Theoretically, it seemed certain that a sea face like that of the Galapagos, bathed as it is by a great current coming from the south and impinging upon its slope, and carrying upon its surface a mass of animal food, could not fail to constitute a most favorable set of conditions for the subsistence and development of a rich deep-sea fauna.

On leaving the Galapagos we took up a former line of the "Albatross" run off Indefatigable Island, hoping to obtain from that quarter our best results, but our hauls were very disappointing. The ground proved not only most difficult to dredge upon, but also comparatively barren, and it was not till we got into the oceanic basin again, between the Galapagos and Acapulco, that our catches improved. But even then they were not to be compared with the hauls at similar depths in the Atlantic off the West Indies, or along the course of the Gulf Stream.

In the first cruise we also found great difficulty in trawling, owing to the considerable irregularities of the bottom. When trawling from north to south, we seemed to cut across submarine ridges, and it was only while trawling from east to west that we generally maintained a fairly uniform depth.

In the Panamic region proper, — the region occupied by our track to Cocos, to Malpelo, and back to Panama, and from there to Galera Point, the Galapagos, and on toward Acapulco, — the most interesting things we found were representatives of the Ceratias group of Fishes, which the naturalists of the "Albatross" tell me they have not met before on the west coast of North America. I may also mention many types of Macruridæ and of Ophidiidæ, fine specimens of Bathyonus, of Bathybrissa, and of Bathypterois, and a few specimens of Ipnops in excellent condition. The Crustacea have supplied us with a most

remarkable type of the Willemœsia group (Eryoneicus), together with the many types characteristic of muddy bottoms, as Glyphocrangon, Notostomus, Heterocarpus, Pentacheles, and Nematocarcinus, many of which we afterwards dredged in the Gulf of California. I may mention one haul which contained a goodly number of a species of Nephrops. The paucity of Echini is most striking, although we brought up in one of the hauls numerous fragments of a gigantic species of Cystechinus, subsequently dredged in the channel between Galera Point and the Galapagos, as well as in the Gulf of California. The occurrence of Cystechinus so far north is interesting; the specimens collected by the "Challenger" came from the Southern Ocean, and a fossil species of the genus has been described by Gregory from Barbados. Other Echini characteristic of muddy bottoms, such as Aspidodiadema, Urechinus, Pourtalesia, and Schizaster, were brought up from deep water, while on rocky bottom we found Salenia and some species of Cidaridæ, all closely allied to their West Indian representatives. The number of Ophiurans was remarkably small as compared with the fauna of deep waters on the Atlantic side, where it often seems as if Ophiurans had been the first and only objects created. The absence of deep-sea corals is also quite striking. They play so important a part in the fauna of the deeper waters of the West Indies, that the contrast is most marked. Gorgoniæ and other Halcyonoids are likewise uncommon. We found but few Siliceous Sponges, and all of well known types. Starfishes are abundant, and are as well represented in the variety of genera and species as on the Atlantic side of the Isthmus. I may also mention the large number of deep-sea Holothurians (Elasipoda) which we obtained, as well as a most remarkable deep-sea Actinian, closely allied to Cerianthus, but evidently belonging to a new family of that group. We found occasionally, when trawling over the region of green mud, large tracts of mud tubes; they belong to the usual types of deep-sea West Indian Annelids.

In the deeper parts of the channel between Galera Point and the southern face of Chatham Island we found a great number of Elasipoda, among them several genera like Peniagone, Benthodytes, and Euphronides, represented by numerous species. The Starfishes of the second part of our cruise did not differ materially from those collected during our first trip, but we added some fine species of Freyella, Hymenaster, Astrogonium, Asterina, and Archasteridæ to our collections. Among the Sea-urchins on two occasions we brought up fine hauls of a species of Cystechinus with a hard test, many specimens of which were in admirable state of preservation. Among the Ophiurans nothing of importance

was added, unless I may except a lot of Ophiocreas attached to a Primnoa, and a pretty species of Sigsbeia attached to a species of Allopora, from the south side of Chatham Island.

The Gorgonians were remarkably few in number. This is undoubtedly due to the unfavorable nature of the bottom we worked upon.

From the nature of the bottom we naturally expected rich hauls of Siliceous Sponges, but we did not find many, and I do not think there are many novelties among those we have collected. On two occasions, a number of specimens of Ascidians were brought up; among them was a fine white translucent Corinascidia.

Among the Bryozoans, the most noteworthy haul was a number of beautiful specimens of the delicate Naresia (Kinetoskias), in excellent condition. On the line from the Galapagos to Acapulco we brought up a good many Foraminifera from the mud bottoms. On several occasions the bottom must have been covered with huge masses of a new type of an arenaceous Foraminifer, forming immense curling sheets attached by one edge to stones or sunk into the mud. This Foraminifer seems to increase in size by forming irregular more or less concentric crescent-shaped rings. When it comes to the surface, it is of a dark olive-green color. This and a species of Rhabdamina allied to R. lineata were the most striking Foraminifera collected.

Among the Worms, the Maldaniæ, Halinæcia, Terebella, and limicolous types were unusually abundant at some localities, the empty mud tubes often filling the bottom of the trawl. Some very large specimens of Trophonia were collected, and remarkably brilliantly colored (orange and carmine) Nemerteans and Planarians.

The Mollusks were comparatively few in number, and the types eminently Caribbean. The absence of Comatulæ or other Crinoids was equally disappointing, even when trawling on the extension of the line started three years ago by the "Albatross," on the eastern face of the Galapagos slope, when on her way from Chatham Island to San Francisco, although we were fortunate enough to bring up off Mariato Point in 782 fathoms a single fine specimen of Calamocrinus, with a part of the stem and its base, showing the mode of attachment of this genus to be similar to that of the fossil Apiocrinidæ.

Two of the hauls made in the Gulf of California are specially worthy of mention, as being characteristic of the deep-water fauna of the Gulf of California, one made in 995 fathoms and the other in 1,588 fathoms. We obtained in these hauls a number of Ophiomusium and Ophiocreas, some fine specimens of Schizaster, a new genus allied to Paleopneustes,

and also the same species of Cystechinus, with a hard test, and of Phormosoma, which we had obtained before on the line from the Galapagos to Acapulco. Besides these, there came up a number of specimens of an interesting species of Pourtalesia, most closely allied to Pourtalesia miranda, the first type of the group dredged in the Florida Channel by Count Pourtalès.

The deeper haul was especially rich in Holothurians, among them a fine large white Cucumaria, some specimens of Trochostoma, several species of Benthodytes, some of them remarkable for their white color, their huge size, and the comparatively small number of ventral tentacles. With these were numerous specimens of an interesting species of Euphronides. In this haul I was specially struck with the Elasipoda, and the great variety in the consistency of the skin in individuals of one and the same species; it varied in different individuals from extreme tenuity to a comparatively tough gelatine-like consistency. On carefully sifting the mud, we found a number of interesting Foraminifera, and of delicate and minute Gasteropods and Lamellibranchs, fragments of the shell of an Argonauta, and two species of a huge ribbed Dentalium. Among the Starfishes were specially noticeable a large Brisinga, a long-armed Cribrella, and several species of Astropecten. The usual types of Worms were found in the mud at these greater depths. In addition to a number of Macruroids, we obtained a pink Aphyonus, a large black Beryx-like fish, a fine Nettastoma, and a couple of species of Lycodes. The usual surface species of Stomias and of Scopelus also came up in the trawl. Among the Crustaceans were a fine lot of Arcturus, of Colossendeis, of Glyphocrangon, and of a Caridid with a deep blue patch on the base of the carapace, making the strongest possible contrast to the dark crimson coloring of the rest of the body. Blue is a very unusual color in the deep-sea types, although the large eggs of some of the deep-sea Macrurans are often of a light blue tint.

We brought up in the trawl at various times, and subsequently also in the Tanner net, from depths of less than 200 fathoms, the same gigantic Ostracod which I mentioned before, several specimens of Atolla, and fragments of a huge Periphylla, which must have been at least fifteen inches in diameter; also a most interesting new type of Bougainvillia, remarkable for having eight clusters of marginal tentacles, but only four chymiferous tubes. Of course neither these Acalephs, nor some of the Beryx-like fishes, of the Scopelids, Stomias, Melamphaës, and the like, which were brought up from less than 300 fathoms by the Tanner net, can any longer be considered as part of the deep-sea fauna.

After passing the Tres Marias, we made several hauls, and obtained some Umbellulæ, Pennatulæ, Trochoptilum, Anthoptilum, and a fine Antipathes, a few Comatulæ, a large Astropecten, some fine specimens of Urechinus and of Schizaster, a few Holothurians, Lophothuria, and Trochostoma, and two species of Elasipoda, besides a few fragments of Gasteropods, with an empty shell of Argonauta.

Among the Crustacea there came up the usual types found living upon muddy bottom, such as Glyphocrangon, Heterocarpus, Notostomus, Pentacheles, Nematocarcinus, and Nephrops, together with species of Lithodes and of Munida. The usual types of limicolous Annelids were also found here, Halinæcia, Terebella, Maldania, and the like; a few Ophiurans, Ophiopholis and Ophiocantha; a few fragments of Farrea, and a huge Hyalonema of the type of H. toxeres. Among the Fishes there were a few Macruridæ, Bathypterois, Lycodes, and Malthe.

Comparison of the Deep-Water Echini obtained in the Panamic and Caribbean Districts.

There will naturally be considerable delay in obtaining the results even of the preliminary examination of the collections sent to the different specialists. To illustrate, therefore, somewhat more in detail the contrasts between the deep-water fauna of the Panamic and of the Caribbean districts, I will make here a very general comparison of the Echini collected on the two sides of the Isthmus of Panama. The identifications here given are of course subject to the revision of the closer and final determination of the collections. This subject will later be fully illustrated by comparative tables of the distribution of the species on the two sides of the Isthmus.

I may state, in general, that we have discovered in the deep-sea fauna of the Panamic district only one genus of Sea-urchins, allied to Salenia, not previously represented on the Atlantic side. The poverty in Clypeastroids was as striking as on the Atlantic side, and in the very heart of the shallow water district so markedly characterized by Clypeastroids on both the Atlantic and Pacific sides we dredged only one specimen of Clypeaster, in 75 fathoms. As in the Caribbean, we find Phormosoma and Asthenosoma; also one species of Aspidodiadema and one of Salenia; Cidaris, Dorocidaris, and Goniocidaris, as well as Porocidaris; which offer an exact parallel in the Pacific to the same genera on the Atlantic side. Of course, how far they are allied a more accurate comparison alone can determine. We may, however, call attention to the absence of Arbaciadæ, which as littoral genera are eminently characteristic of

the temperate and tropical American shores. Some of the genera of the family extend into deep water on the Atlantic side, but they have not been found by the "Albatross" in the Pacific Panamic district. Neither Podocidaris nor Cœlopleurus was dredged by us. The absence of the latter genus is specially noteworthy, as it is found at Mauritius and has been dredged by the "Challenger" in the East Indian Archipelago. The only Pacific genus found in deep water was Maretia. It should be remembered that the genera of Cidaridæ and of Echinothuriæ all have an extensive Pacific, as well as Atlantic distribution. There were no deep-water Nucleolidæ, although they are found in shallow water in the Central American district and in deep water in the West Indian fauna. The occurrence of Echinocrepis, Cystechinus and Urechinus, types characteristic of the Southern Ocean and Southern Pacific, is interesting, associated as they are with Pourtalesia proper, a genus of wide geographical distribution, which, as well as Urechinus, is found in the Caribbean district. The ubiquitous Schizaster and Brissopsis were associated on the Pacific side with Paleopneustes, Homolampas, and Hemiaster, as in the West Indian district; and the remarkable Aërope, which has an extensive geograpical distribution, — it is found in the Arafura Sea and off the eastern coast of North America, — was not uncommon in the Panamic area. Moira, on the contrary, which again is a characteristic American genus on both sides of the continent in the temperate zone, was not obtained by the "Albatross" on her present cruise.

I need at present only to refer to the chapter on the origin of the West Indian Fauna in the report of the "Blake" Echini,[1] where lists will be found of the Cretaceous and Tertiary Echini, and where they are compared with those living in the West Indian and neighboring areas at the present day. It is interesting to note here the occurrence of a species of Cystechinus from the Radiolarian Marls of Barbados, mentioned by Gregory.[2] I understand from him that a species allied to Paleopneustes has also been detected in the same beds. The existence of Cystechinus at Barbados is another link in the evidence of a former connection between the Caribbean and the Pacific, — of a time when, as I have suggested, the Caribbean was probably a bay of the Pacific, — until later cretaceous times; but they gradually during the tertiary period[3] became

[1] Mem. Mus. Comp. Zoöl., Vol. X. No. 1, and Three Cruises of the "Blake," Vol. I. pp. 92, 109–124.

[2] See Quart. Journ. Geol. Soc. London, November, 1889.

[3] See the Memoir of Gabb on the Geology of Santo Domingo, in the Trans. of the Am. Phil. Soc., Vol. XV., 1873, pp. 49-259.

separated by elevations which finally left the Caribbean, up to a comparatively recent time, only connected with the Pacific, as it is to-day with the Atlantic, merely by narrow passages.

The Color of Deep-Sea Types.

During our cruise a good deal of attention was given to making colored sketches of as large a number of deep-sea types as possible. There is among them considerable variety as well as range of coloration. Although it is true, as has been noticed by Thomson and others, that the violets, reds, and purples are the prevailing colors, yet we find also a number of forms in which yellows prevail, as, for instance, in the Comatulæ and in Calamocrinus; the yellow in the latter genus passing to a greenish tinge, in the Comatulæ to a reddish tinge, or even to brilliant red as the principal tint. In the Crustacea the deep-sea types like Gnathophausia, Notostomus, and Glyphocrangon are of a brilliant scarlet; in some types, as in the Munidæ and the Willemœsiæ, the coloration tends to pinkish, or yellowish pink, while in Nephrops and Heterocarpus the scarlet passes more into greenish tints and patches. The color of the deep-sea Pycnogonidæ did not differ from that of the littoral species. The large eggs of some of the deep-sea genera are of a brilliant light blue, and in one genus of Macrura we found a deep dark metallic blue patch on the dorsal part of the carapace, in striking contrast to the brilliant crimson of the rest of the body. Blue is an uncommon color among pelagic animals, and is certainly not specially protective, as is stated by Hensen and others; for the Porpitidæ, Yanthina, Physalia, Glaucus, and a few other types, which form the exceptions, are among the most conspicuous of all surface animals. Many of these, especially among the Acalephs, are colorless, it is true, yet in spite of their transparency often become conspicuous objects from the development of more or less opaque genital organs or actinal appendages.

The Starfishes, as a rule, were of duller hues than the Crustacea, but all more or less tending to pinkish tints, with a greater or less mixture of yellow or orange among the Astrogonidæ on the one side, while on the other the Archasteridæ developed more into pinkish grays or ashy hues. The same was the case with the Brisingidæ. The Hymenasteridæ, on the contrary, varied from light bluish violet to deep reddish chestnut colors. Among the Ophiurans, with the exception of Ophiocreas, which are of a yellowish brick-red, the species we dredged

(mainly from muddy bottoms) were of a dull grayish color, or with a more or less yellowish pink tint. A pretty Sigsbeia attached to an Allopora varied from nearly porcelain-white individuals to specimens more or less belted with bands of ashy violet.

The Pourtalesiæ with thin tests, like the other species of the family already known, were of a delicate pink color; those with stouter shells, of a dark violet or deep claret color. The same is true of Urechinus and of Cystechinus, in which the color varies from a light brownish pink to a pale claret tint.

The species of Asthenosoma were of a deep claret-color, varying from that to light brown, almost straw-color. Some of the Phormosomæ, on the contrary, are usually of a brownish brick-color, others of a deep violet. In Paleopneustes we find the same variation in tints as in the Echinothuriæ.

The coloration of the deep-sea fishes is comparatively monotonous. The tints are all of a light violet base, tending more or less to brownish or brownish yellow, or even to a greenish tint, especially among the Macruridæ. Some of the Liparidæ were of a dark violet, and one species was characterized by a brilliant blue band. The Ophidiidæ, Nemichthys, and the like, are usually of an ashy violet tint, while in Ipnops and Bathypterois the tints were of a decidedly yellowish brown. When we come to questionable deep-sea types, such as the Beryx-like fishes, we find some of them nearly black with a slight violet hue, resembling more in their coloring the prevailing body tints of Stomias and the like, and other fishes which occur within the 300 fathom line from the surface. Among the most strikingly colored fishes we obtained was a species of the Ceratias group, of a brilliant vermilion with yellowish blue patches on the sides, in striking contrast with its Atlantic congeners, which are usually of a blackish tint.

The semi-transparent deep-sea types, like Aphyonus, are usually pinkish, while the Scopelids and the like, which are pelagic fishes, the majority of which do not descend below 300 fathoms, have a dark, almost black coloration, in striking contrast with their silvery flanks, which often carry phosphorescent organs. In a species of Stomias there is on the sides a wide band, gradually tapering towards the tail, of a brilliant yellow.

Among the Holothurians we noticed the greatest variety in the coloring. In one species the color was of a delicate green tinge. Trochostoma does not differ greatly in coloration from its littoral allies. We obtained a white Cucumaria and some species of Benthodytes of the same color.

Peniagone and its nearest allies varied from a transparent milky white to yellow and light yellowish brown. Others again were of a pinkish color.

Deima, Orphnurgus, and their allies, were of a light brown or of a dirty yellow color. Benthodytes and Euphronides, with the exception of a few translucent specimens of a whitish tint, varied from a reddish violet to a deep claret, or to reddish with pronounced bluish tints, and one fine specimen of the group was of a bluish color with delicate violet shades passing into whitish milky blue.

Psychropotes and allied genera were of a reddish violet color on the dorsal side, with bluish violet of a lighter shade on the ventral surface.

The Maldaniæ, Serpulæ, and Terebellæ did not differ in their type of coloring from their littoral congeners.

The coloring of the so called deep-sea Acalephs, Periphylla, Atolla, and the like, has already been noted; it is usually of a deep violet or yellowish red. Although they have the characteristic coloring of many of the deep-sea types, yet they are known to live within comparatively shallow limits, inside the 200 fathom line, and even to come to the surface.

A species of Stomobrachium was remarkable for its light carmine color, a tint hitherto not observed among Acalephs.

The color of the Cephalopods, like that of the Acalephs, is limited mainly to violet, both in types which are undoubted deep-sea species and in those which are certainly pelagic.

Among the deep-sea Actiniæ, a species of a new Cerianthus was of a dark brick-red, while other Actinians allied to Bunodes were of a deep violet. Actinauge-like forms with tentacles of a pinkish violet tinge frequently have the column of a yellow shade. The Zoanthidæ were grayish green.

We cannot fail to be struck in this enumeration of colors with the preponderance of violet shades, as also with the great variety in tints, and their apparent absence of adaptation to the surrounding greenish gray waste of mud in which a fauna so diversified in coloring flourishes.

This variation in coloring extends to species of the same group, and is specially marked among the Holothurians. Among the Fishes and Crustaceans it is less so, the former having to a great extent apparently assumed the grayish or brownish shades of their surroundings; while in the Crustacea nothing could be more marked than the contrast between the brilliant coloring of the group and the dull surface upon which they

dwell. In the Holothurians as well as in the Actinians we find both the contrast and the apparent adaptation to the surroundings.

This great diversity in coloration brings up interesting questions regarding the influence of the environment upon the fauna at great depths. But until we know more of the effects produced by the penetration of light through such masses of water, speculations as to their cause cannot rest upon a very substantial basis.

It is difficult to understand how so great and numberless variations may have been brought about, or to account for such a case of mimicry as was observed in a crab allied to the Maiadæ, in which the dorsal face of the carapace appears like a bit of muddy area covered by corals, with a huge white arm resembling a fragment of an Isis-like Gorgonian.

At present the simplest explanation is that suggested by Moseley, that the deep-sea types have little by little found their way into greater depths from the littoral limits, and have retained or lost many of the features characteristic of their littoral predecessors under conditions radically different from those existing in the abysses of the sea. As denizens of the littoral belt, they were subject to all the disturbing influences of the action of light, of heat, of a varying supply of food, and to a certain extent of the motion of the water. All these conditions are in striking contrast to those we may imagine to exist at great depths, where little change can be produced by whatever light may find its way to the bottom of an oceanic basin, where the temperature is uniform, where there is no motion, and where in fact all the factors we are accustomed to associate with marine life as we see it on our shores are practically wanting.

EXPLANATION OF THE PLATES.

PLATE I.

Modified Chun-Petersen Tow-Net.

Fig. 1. The net ready to lower.
Fig. 2. The net opened, ready to tow horizontally at the required depth.
Fig. 3. The net closed on its way up to the surface.

For lettering, see the description of the net, page 45.

PLATE II.

Tanner Deep-Sea Tow-Net.

Fig. 1. Sketch of the Tanner tow-net open.
Fig. 2. Messenger for closing the net, sliding on wire rope.
Fig. 3. Sinker attached above the Tanner net.
Fig. 4. Bell crank tripped by messenger to liberate the slings.
Fig. 5. Attachment of bell crank to wire rope.
Fig. 6. Showing the lower part of the Tanner net when closed.

For lettering, see the description of the Tanner tow-net, pages 46, 47.

PLATE III.

Hydrographic Sketch of the Pacific, from the Gulf of California to Northern Ecuador, with the Track of the "Albatros."

PLATE IV.

Sketch of the Galapagos Islands, with the Track of the "Albatross."

The sounding of 329 fathoms to the east of Indefatigable Island should read 392 fathoms.

PLATE V.

Temperature Section and Profile, from Mariato Point to Cocos Island.

February 23d to February 28th.

PLATE VI.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Cocos Island to Station 3375, a point 100 miles southwest of Malpelo Island. March 1st to March 4th.

Fig. 2. From Station 3375 to Malpelo Island, to Rey Island, one of the Pearl Islands in the Bay of Panama. March 4th to March 11th.

PLATE VII.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Station 3392, thirty miles southeast from Point Mala, to Caracoles Point.

Fig. 2. From Station 3392, thirty miles southeast from Point Mala, to Point Mala.

Fig. 3. From Station 3383, fifty miles southeast from Caracoles Point, to Panama.

PLATE VIII.

TEMPERATURE SECTION AND PROFILE.

From north of Galera Point to off Galera Point, to Chatham Island, one of the Galapagos. March 23d to March 28th.

PLATE IX.

TEMPERATURE SECTION AND PROFILE.

From off Chatham Island to off James, to between Abingdon and Wenman Islands, to Acapulco. April 3d to April 12th.

PLATE X.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From north of Wreck Bay, Chatham Island, to Station 3408, six miles southwest of Bindloe Island.

Fig. 2. From Indefatigable Island to Bindloe Island.

Fig. 3. From Gordon Rocks, Indefatigable Island, to 332 fathoms, in an easterly direction.

Flg. 4. From north of Sulivan Bay, James Island, to Station 3407.

PLATE XI.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Charles Island to Indefatigable Island.
Fig. 2. From Charles Island to Hood Island.
Fig. 3. From Hood Island to Chatham Island.
Fig. 4. From three miles south of Wreck Point, Chatham Island, to Station 3401.
Fig. 5. From ten miles northwest of Wreck Bay, Chatham Island, to twenty miles northeast of Hobbs Reef, Chatham Island.

PLATE XII.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Hydrographic Station 2630, eleven miles east of Wenman Island, to Abingdon Island.
Fig. 2. From Hydrographic Station 2630 to Wenman Island.

PLATE XIII.

VEGETATION OF COCOS ISLAND, CHATHAM BAY.

PLATE XIV.

MALPELO ISLAND, SEEN FROM THE WESTWARD.

PLATE XV.

CORAL SAND FLAT, BACK OF THE LANDING BEACH AT WRECK BAY, CHATHAM ISLAND.

PLATE XVI.

VEGETATION CHARACTERISTIC OF THE BARREN BELT ON THE WAY TO THE COBOS HACIENDA, CHATHAM ISLAND.

About a mile from the landing at Wreck Bay.

PLATE XVII.

FERTILE HIGH PLATEAU OF CHATHAM ISLAND.

Seen looking east from the Cobos Hacienda.

PLATE XVIII.

LAVA BLOCKS WEST OF BLACK BEACH, CHARLES ISLAND (FLOREANA).

PLATE XIX.

LAVA ROCKS AND BLACK BEACH, CHARLES ISLAND.

PLATE XX.

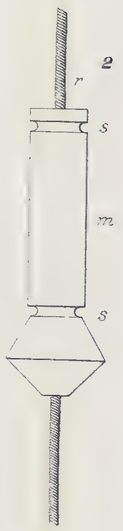
VEGETATION NEAR BLACK BEACH, CHARLES ISLAND.

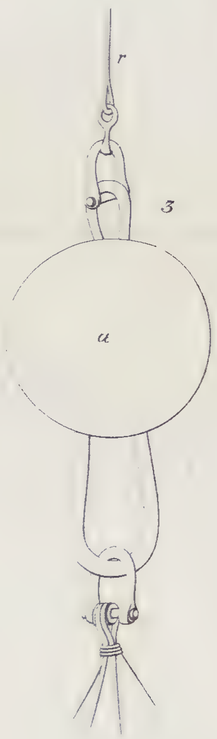
PLATE XXI.

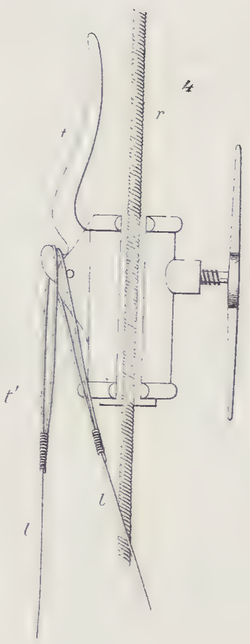
VEGETATION ON THE WAY TO THE ABANDONED VILLAMIL HACIENDA, CHARLES ISLAND.

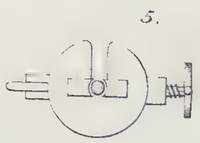
PLATE XXII.

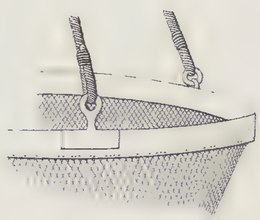
PART OF EASTERN FACE OF DUNCAN ISLAND, NEAR THE LANDING COVE.

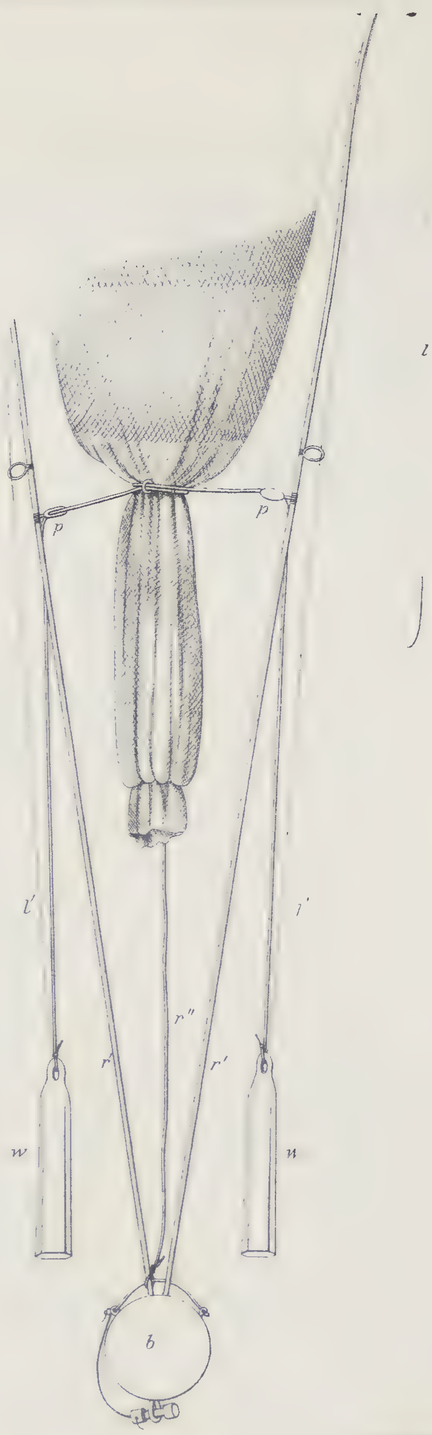












B.Meisel,lith Boston

EXPLORATIONS OF THE
U.S. FISH COMMISSION
STEAMER ALBATROSS
Lieut. Comdr. Z.L. Tanner, U.S.N. Comdg.
February to April 1891
Compiled from the latest U.S. Hydrographic Office charts with additions by the U.S.F.C. Steamer Albatross
Soundings represented thus 2256 are by the U.S.F.C.S.S. "Albatross" 1888 1889 1891
100 fathom lines shown thus
500
1000
1500
2000
Rocks are from other sources
P. Pablos Co coral, Gr grampus, M mud, S sand, Sh shells
Sp Spatic, G gravel, Rm fine red mud, Wh white
Bk black, R red, Gy grey, Sy grey, V yellow, Br brown, dk dark, l light
MEXICO
GUATEMALA
HONDURAS
SALVADOR
NICARAGUA
COSTA RICA
COLOMBIA
GULF OF MEXICO
CARIBBEAN SEA
GULF OF CALIFORNIA
Guaymas
Agiabampo
Topolobampo
Altata
Mazatlan
San Blas
Banderas Bay
Manzanillo
Maruata
Petacalco Bay
Acapulco
P. Angeles
Salina Cruz
Tehuantepec
La Puerta
Champerico
S. Jose
Acajutla
La Libertad
Corinto
Gulf of Fonseca
Nicoya
Gulf of Dulce
C. Mala
Panama
Gulf of Panama
Chiriqui
Corrientes
C. San Francisco
C. San Lorenzo
Cocos I.
Malpelo I.
Gallapagos Islands
Track of the U.S.F.C.S.S. "Albatross" 1891
Revilla Gigedo Islands
Socorro
Clarion I.
Roca Partida
Duncan I.
Culpepper I.
Wenman I.
Abingdon I.
Bindloe I.
Albemarle I.
Narborough I.
Tower I.
Barrington I.
Indefatigable I.
Charles I.
Hood I.
Chatham I.
Barkley Sd.
Academy Bay
Post Office Bay
Black Beach Road
Stevens Bay
Cormorant Bay
Tagus Cove
Elizabeth Bay
Banks Bay
Albemarle Point
Duncan Bay
Barrington Bay
Gardner Bay
Hood Bay
Chatham Bay
Wreck Bay
Post Office Bay
Panama Bank
Fathoms
Soundings

GALAPAGOS ISLANDS

SHOWING EXPLORATIONS

OF THE

U. S. FISH COMMISSION STEAMER "ALBATROSS"

Lieut-Comdr. Z.L.Tanner U.S.N. Comdg.

February to April 1891

Soundings represented thus: 671, are by the U.S.F.C.Str 'Albatross' 1888
" " " 885, " " " " " 1891
" " " 100, " from other sources.

P. Pebbles, Co. coral, Gl. globigerina, S. sand, Sh. shells, M. mud, O. ooze, Sp. specks. fne. fine, hrd. hard, rky. rocky, bk. black, wh. white, gy. gray, yl. yellow, brk. broken, dk. dark

Soundings shown thus 80 are negative

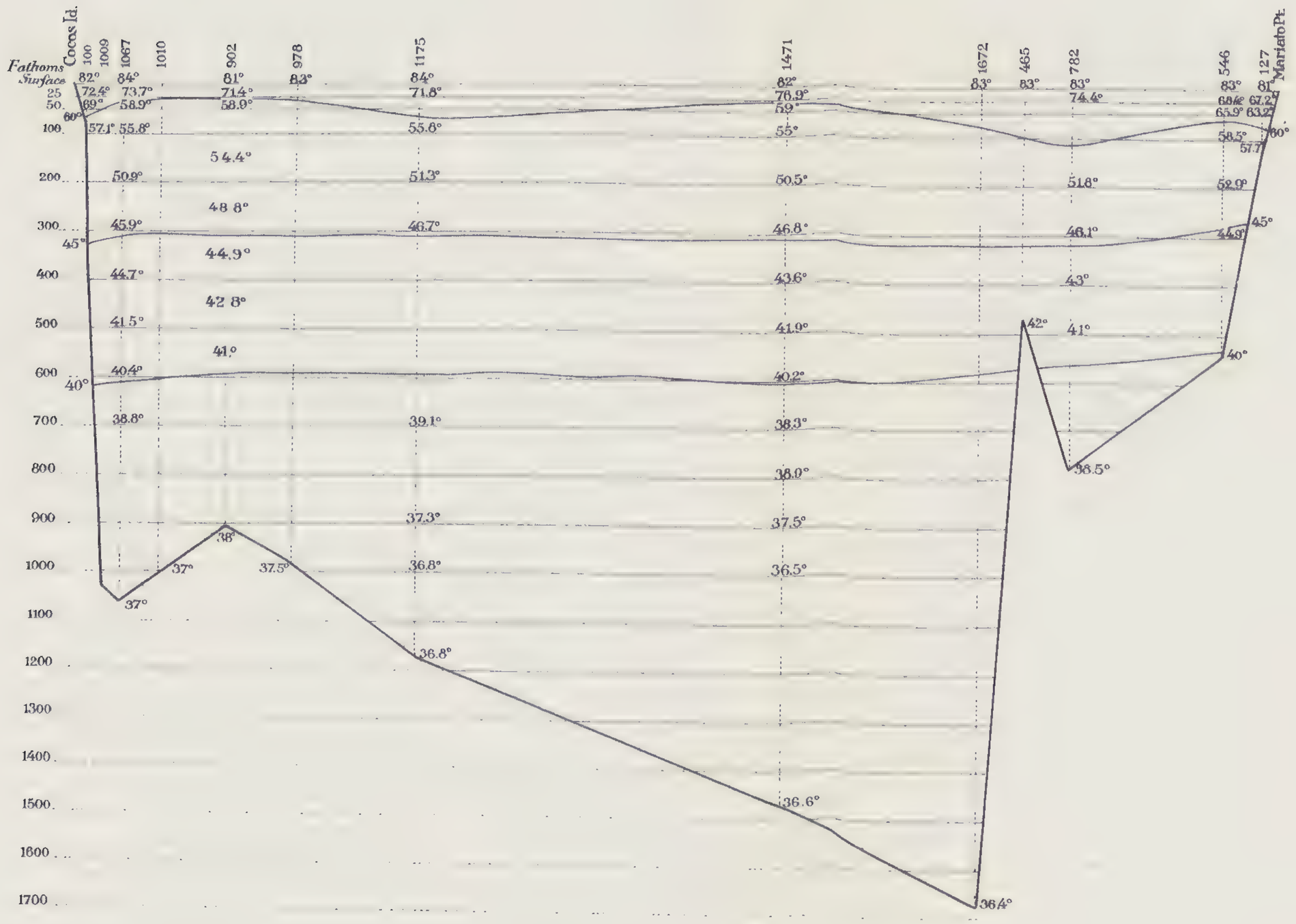
From B.A.Chart No. 1375

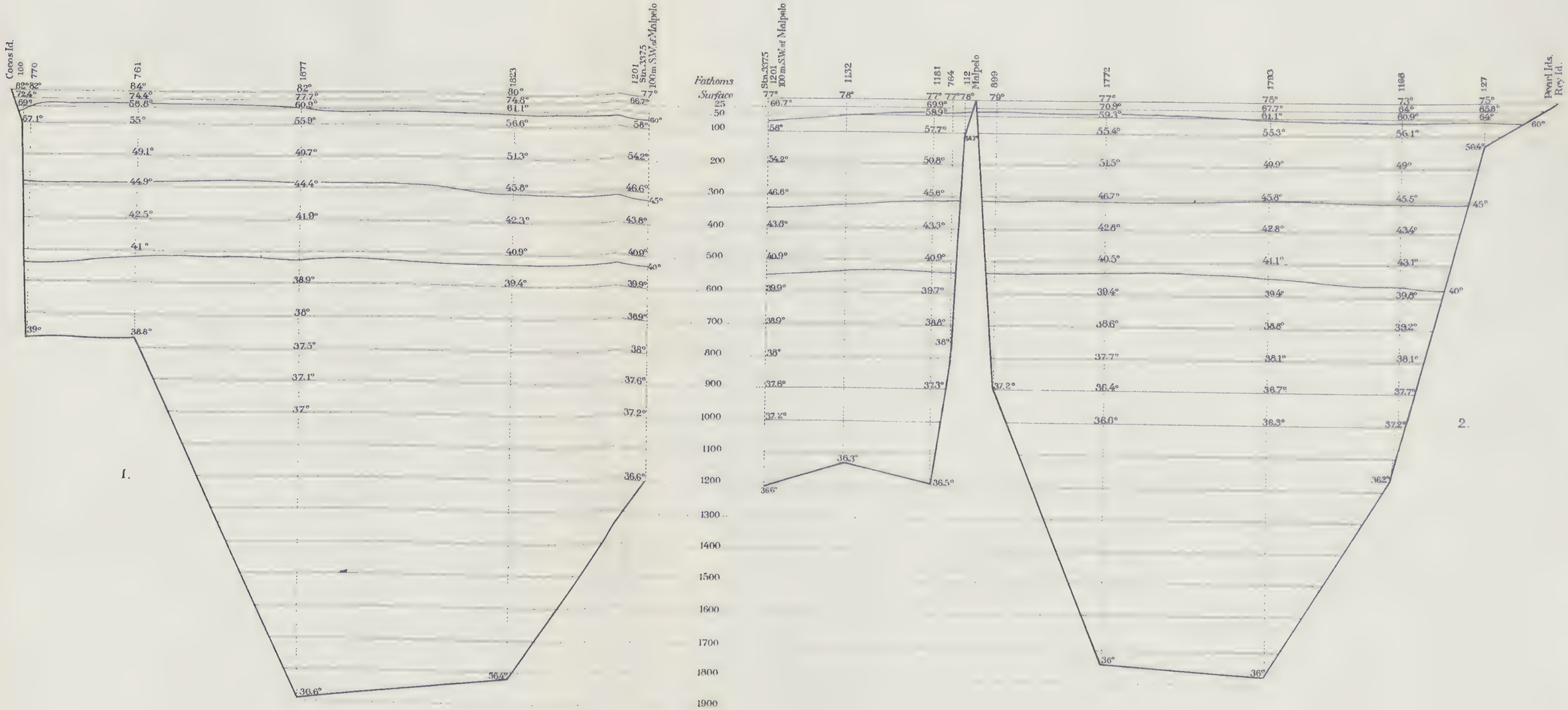
Track of the U.S.F.C.Str Albatross 1891

92° 30′ 91° 30′ 90° 30′ 89°

2° 30′ 1° 30′ 0° 30′ 1° 30′ 2°

Culpepper I (650ft)
Wenman I (830 ft)
Redonda Rock (85 ft)
Albemarle Pt
C. Berkeley
C. Marshall
Black Bight
C. Douglas
NARBOROUGH I.
C. Hammond
Elizabeth Bay
Christopher Pt
Iguana Cove
Essex Pt
Webb Cove
Albany I
James Bay
ALBEMARLE I.
C. Nepean
Cowley I
Jervis I
Abingdon I
C. Chalmers
C. Ibbetson
Bindloe I
Tower I
Sullivan Bay
Seymour Is
Daphne Is
Guy Fawkes Is
Conway Bay
White Rk
Duncau I
Nameless I.
INDEFATIGABLE I.
C. Woodford
Grossman Is.
Barrington I
Brattle I
Post Office Bay
Blackbeach Rd
Charles I
Enderby I (330 ft)
Caldwell I
Gardner I (780 ft)
Watson I
Hood I
Gardner Bay
Macgowen Reef
Stephens Bay
Wreck Bay
Freshwater Bay
Gordon Rks
Ripple Rk
Kicker Rk
Dalrymple Rk
Terapin Rk
Finger Pt
Mt. Pitt
Hobbs Rf
East Rk
Whale Rk
Wreck Rk
Ripple Rk
Tower I

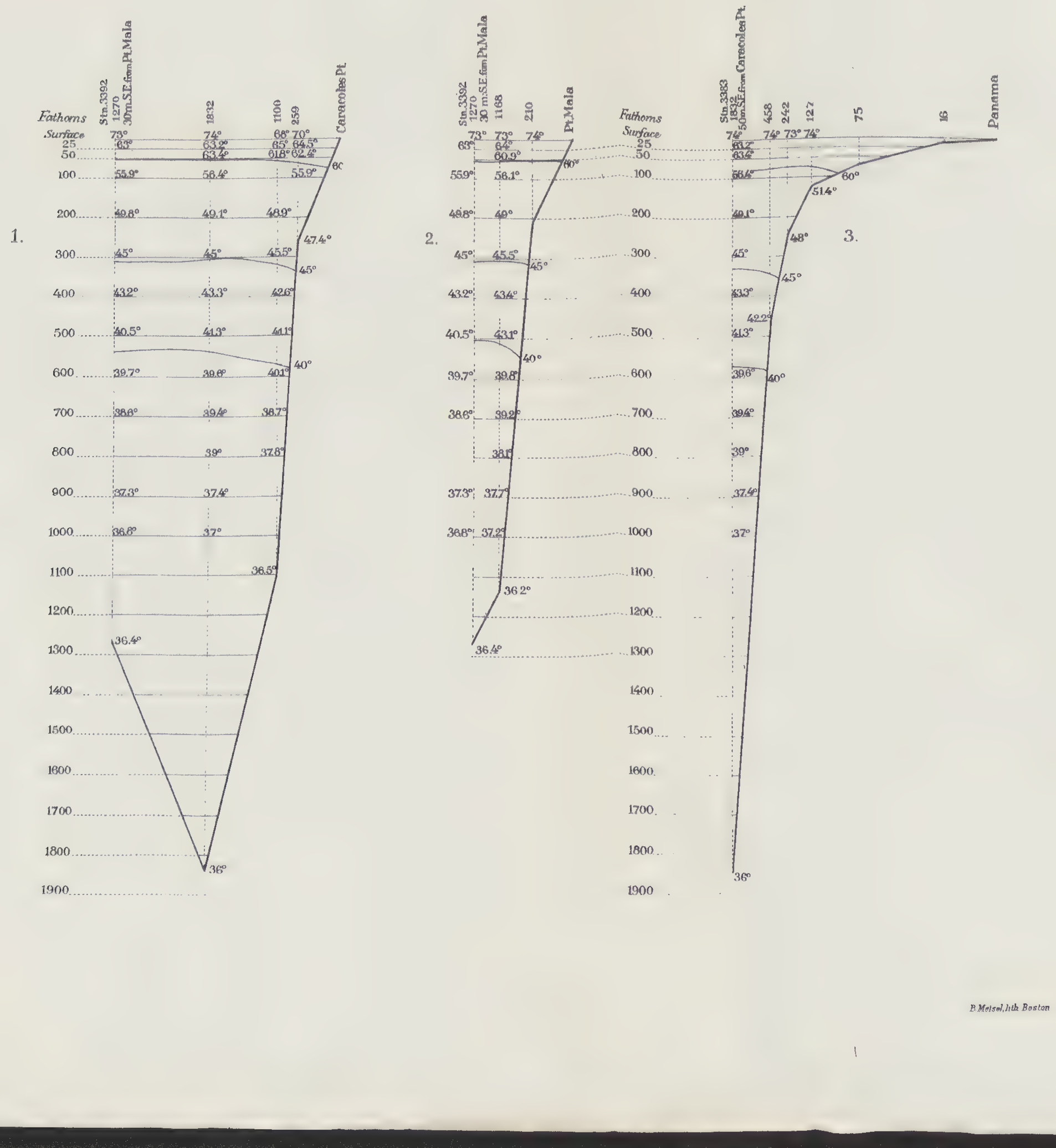

Fathoms
Surface
25
50
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
Cocos Id.
100
1009
1067
1010
902
978
1175
1471
1672
465
782
546
127
Mariato Pt.
82° 84° 81° 83° 84° 82° 83° 83° 83° 83° 81°
72.4° 73.7° 71.4° 71.8° 76.9° 74.4° 67.2°
69° 58.9° 58.9° 59° 66.2° 65.9° 63.2°
60° 57.1° 55.8° 55.8° 55° 58.5° 57.7° 60°
54.4° 50.9° 51.3° 50.5° 51.8° 52.9°
48.8° 45.9° 46.7° 46.8° 46.1° 44.9° 45°
45° 44.9°
44.7° 43.6° 43°
42.8° 41.5° 41.9° 42° 41°
41° 40.4° 40.2° 40°
40° 38.8° 39.1° 38.3°
38.0°
38.5°
37.3° 37.5°
38° 37° 37.5° 36.8° 36.5°
37°
36.8°
36.6°
36.4°



1.

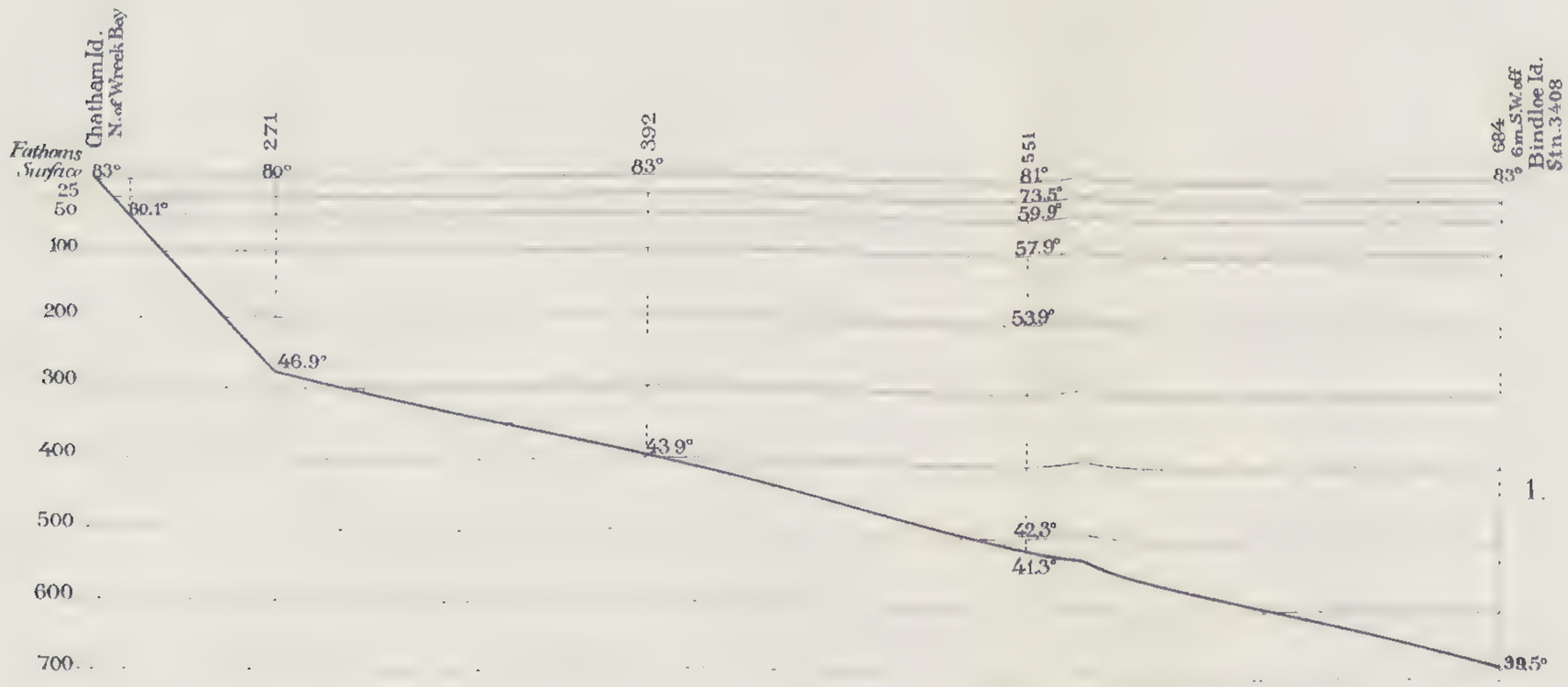
2.

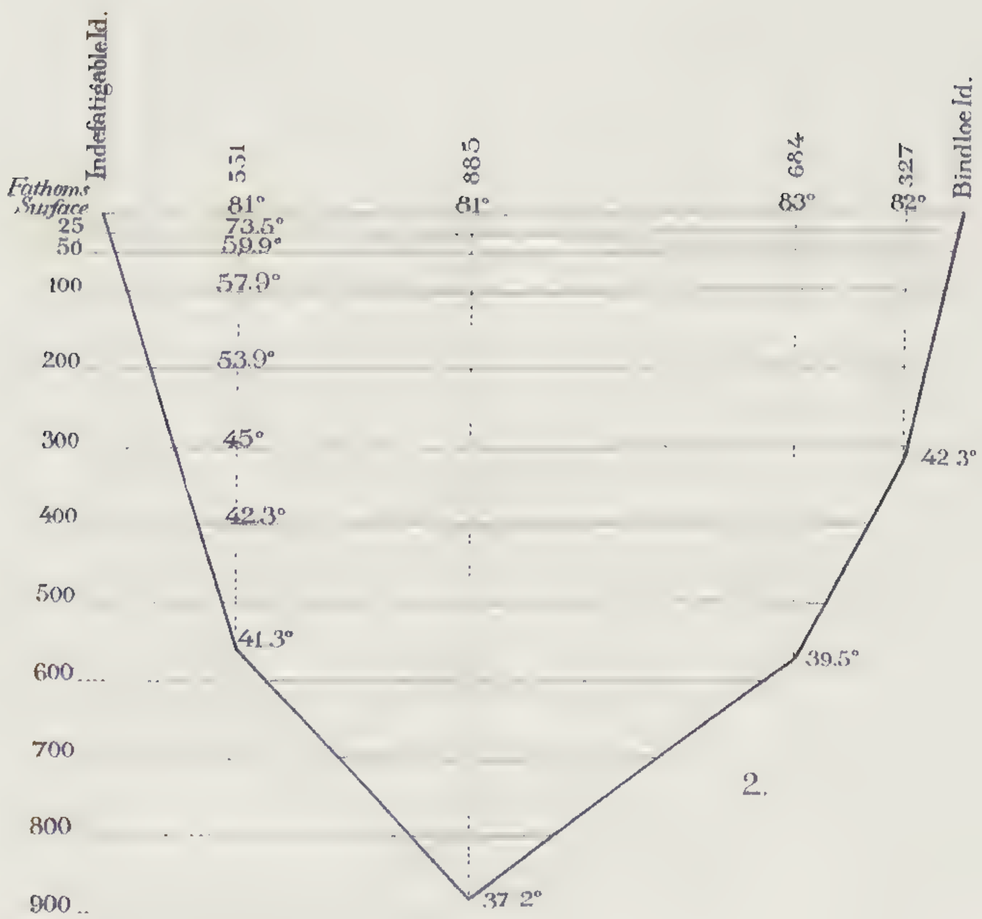
B. Meisel lith. Boston

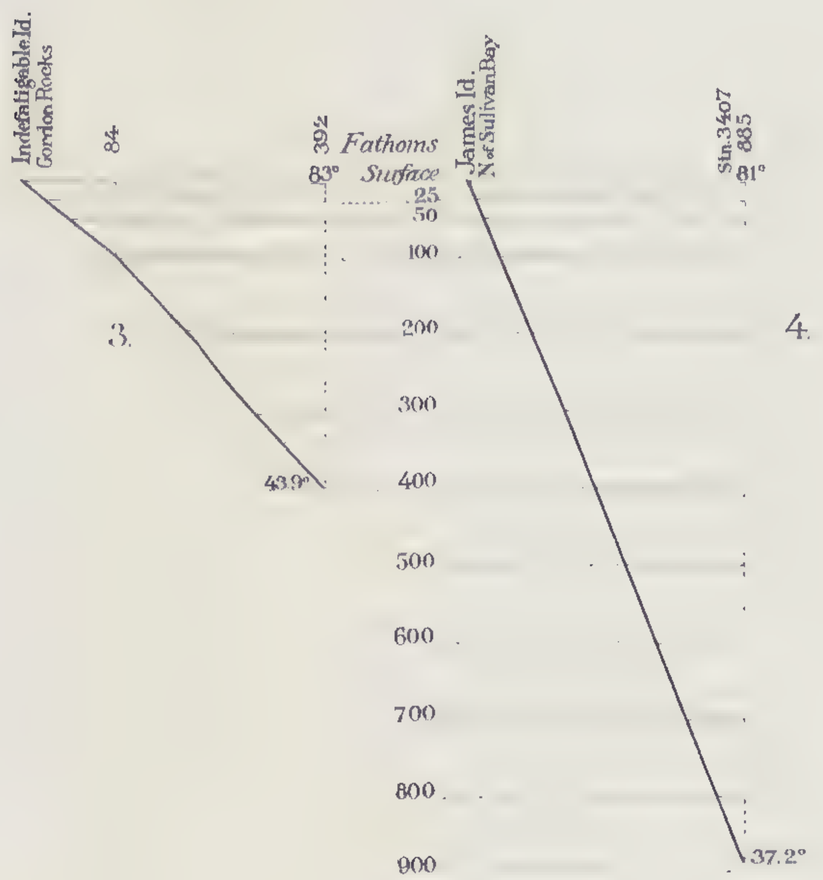


B.Meisel, lith. Boston

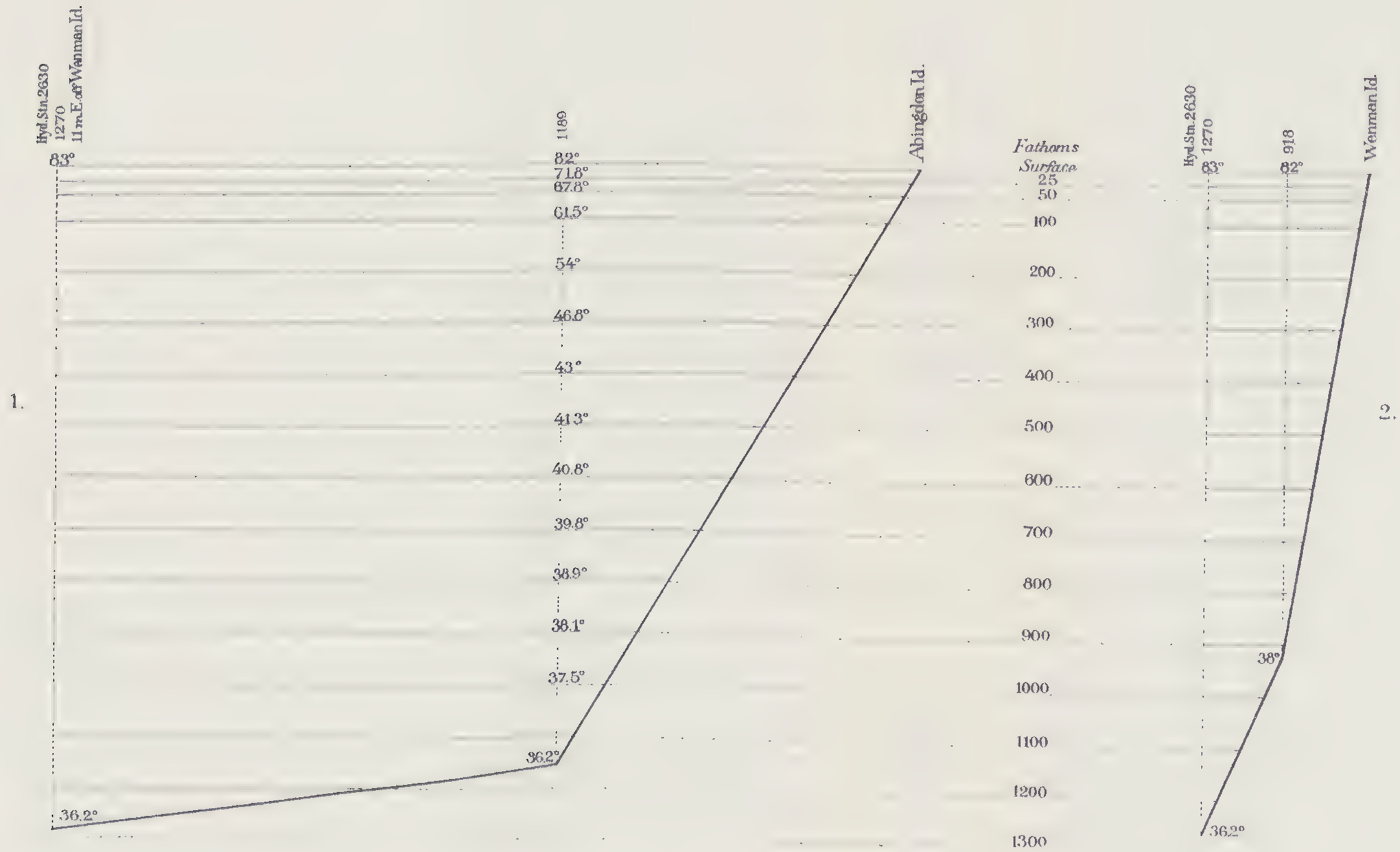
B Metsel, lith Boston



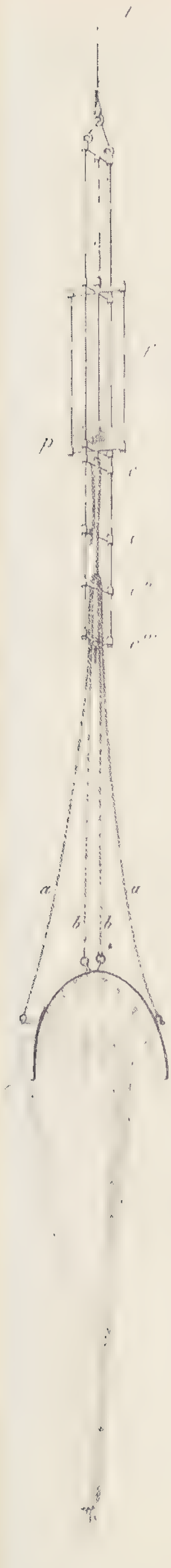




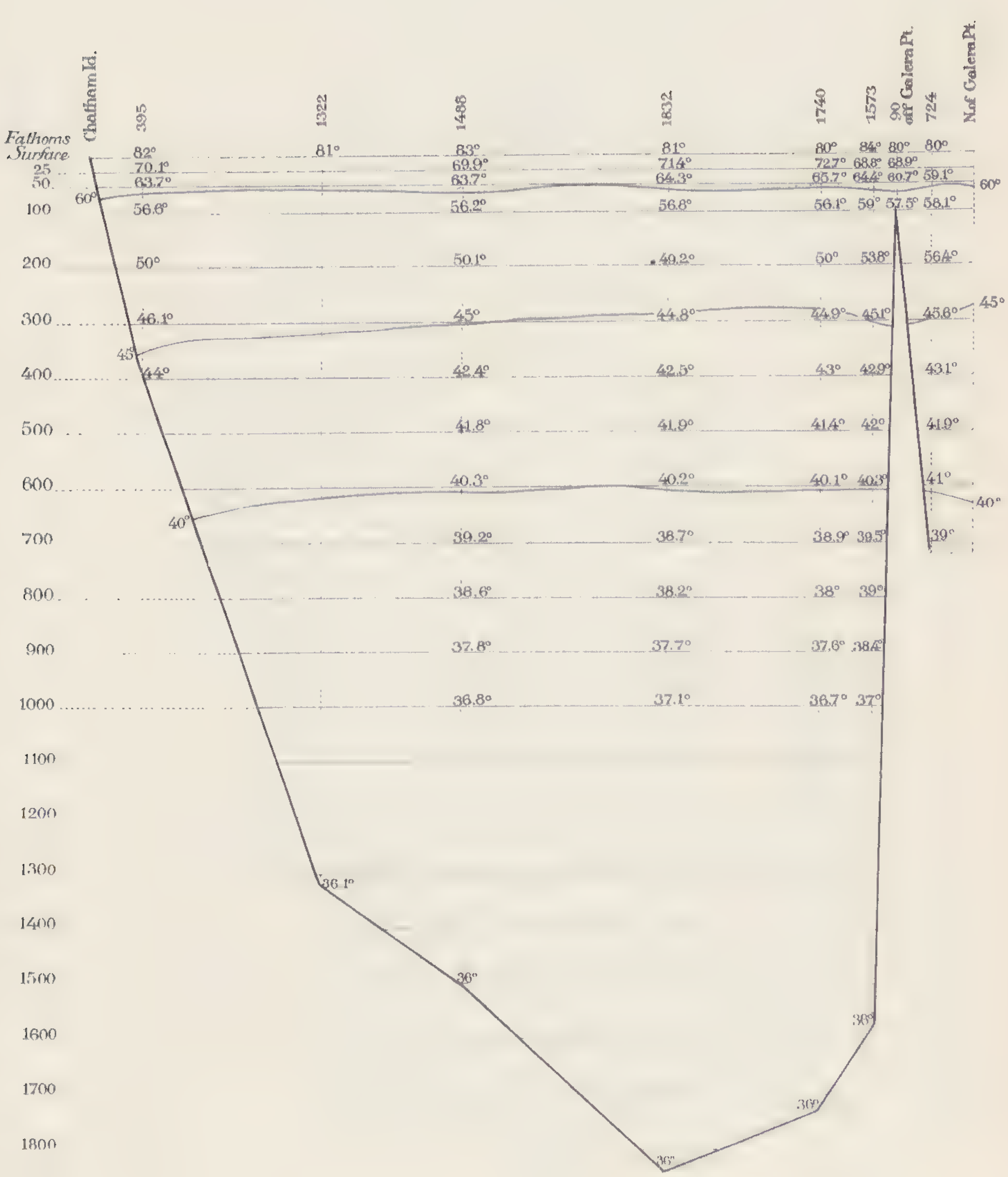
B Meisel, lith Boston



B Meisel, lith Boston



J. Meisel, lith. Boston



B Meisel lith Boston

Fathoms
Surface
25
50
100
200
300
400
500
600
700
800
900
1.
Charles Id.
13
49
56
56
74
102
54
61
Indefatigable Id
2
Charles Id.
48
191
286
Hood Id.
70°
80°
53.9°
45.9°
3.
Hood Id.
66
287
53
Chatham Id.
78°
83°
60.1°
45.9°
4.
off Chatham Id. 3 m.S.of Wreck Pt
56
334
421
395
Sn.3401
82°
82°
82°
70.1°
63.7°
56.6°
50°
46.1°
43.3°
42.5°
44°
5.
10 m.N.W.(Chatham Id.) Wreck Bay.
429
271
634
812
20 m.N.E.of Hobbs Reef (Chatham Id.)
80°
79°
79°
46.9°
39.9°
38.3°

N. B MILLER, PHOTO. ARTOTYPE, E. BIERSTADT N. Y.

CHATHAM BAY COCOS ISLAND.

MALPELO I. LANI

FROM TH[illegible]

TYPICAL SAND FLAT BACK OF LANAI, BEACH, WIPEOUT BAY

N. S. MILLER, PHOTO. ARTOTYPE, E. BIERSTADT, N. Y.

ON WAY TO HACIENDA.

CHATHAM ISLAND.

N. B. MILLER, PHOTO.

ARTOTYPE, E. BIERSTADT N. Y.

PLATEAU SEEN LOOKING EAST FROM HACIENDA.

CHATHAM ISLAND.

N. B MILLER, PHOTO

ARTOTYPE, E BIERSTADT N. Y

LAVA BLOCKS WEST OF BLACKBEACH.

CHARLES ISLAND.

ROCKS AND BLACKBEACH.

N. B. MILLER, PHOTO

ARTOTYPE

VEGETATION NEAR BLACKBEACH.

N. B. MILLER, PHOTO ARTOTYPE, E. BIERSTADT N. Y.

CHARLES ISLAND.

VEGETATION ON WAY TO HACIENDA

B. MILLER, PHOTO.

ARTOTYPE, F. BIERSTADT, N. Y

DUNCAN ISLAND

EAST FACE NEAR LANDING COVE

No. 2. — *The Mesoderm in Teleosts: especially its Share in the Formation of the Pectoral Fin.* By E. R. Boyer.[1]

Table of Contents.

	Page
I. Introduction	91
II. Preliminary Account	93
(*a*) The Material	93
(*b*) Technique employed	93
(*c*) Variation in the Development of Fundulus	94
III. Summary of the Literature on the Development of Paired Fins in Fishes	95
(*a*) Teleosts	95
(*b*) Elasmobranchs, etc.	99
IV. The Axial and Parietal Mesoderm	102
(*a*) Formation of the Primitive Layers, and the Differentiation of Protovertebræ and Lateral Plates	102
(*b*) Topography of the Embryo	104
(*c*) Differentiation and early Development of the Mesoderm in the Pectoral Region	104
V. Intermediate Cell-mass	110
(*a*) Review of the Literature	110
(*b*) The Origin of the "Intermediate Cell-mass" in Fundulus	114
(*c*) Concerning the Fate of the "Intermediate Cell-mass"	116
(*d*) Comparative Review	120
VI. Origin of the Pectoral Fin	122
(*a*) Proliferation of Somatopleure	122
(*b*) Contribution of Myotomic Elements to Pectoral Plates	123
VII. Concerning the Relation of the Pectoral Plate and the Ectodermal Fold	126
Bibliography	131
Explanation of Figures	134

I. Introduction.

Balfour was the first to study the ontogeny of the paired fins in Elasmobranchs with sufficient fulness to determine the source of the musculature. His discoveries practically ended the discussion which was aroused by the widely different views concerning the phylogenetic origin of the vertebrate limb advocated by Thacher, Mivart, and Balfour on the one hand, and by Gegenbaur and Huxley on the other.

It is a well established rule, that, in the development of the paired limbs of Vertebrates, the earliest trace is a lateral ectodermal fold or diverticulum, into which subsequently the indifferent mesoderm grows

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXI.

to form the rudimentary limb; and it is well known that, in some forms at least, in the further development of this rudimentary limb, or limb-bud, there are contributed by the myotomes secondary mesodermal elements which are destined to form its skeleton and musculature.

It has been my purpose in this paper to determine, if possible, the source of the mesoderm which enters into the formation of the paired fins of Teleosts, and to ascertain to what extent Fundulus conforms to this general rule. This problem involves, to a greater extent than I had anticipated, the early differentiation of the mesoderm itself, and indeed the origin of the mesoderm; but the latter subject, although very interesting and important, I have been obliged to omit entirely from my present study.

The protovertebræ, the lateral layers, and the structures known as "head mesoderm" and "intermediate cell-mass" are intimately related in their origin, and the source of the mesoderm in the pectoral fin has been referred by various authors to one or more of these structures. I therefore begin my observations with the formation of these parts, and trace their development and relations through the early stages, with a view to ascertaining their connection with the origin of the pectoral fin.

The very high degree of specialization which characterizes the ontogeny of Teleosts renders the investigation of certain questions quite difficult, and problems concerning points of homology and phylogenetic significance are beset with limitations and uncertainty. The extreme variation in the development of different forms of this vertebrate phylum also renders hazardous any attempt to draw general conclusions from the investigation of a single or only a few forms. Hence I cannot hope to place beyond the reach of criticism the conclusions which I have ventured to draw from observations made almost exclusively upon a single form.

This paper is the result of studies carried on during the year 1889–90 in the Zoölogical Laboratory of Harvard University, under the direction of Dr. E. L. Mark, at whose suggestion this problem was taken up. I owe grateful acknowledgment of my obligations to Dr. Mark for the uniformly kind and valuable assistance rendered to me in this work. I am also under great obligations to Prof. Alexander Agassiz, through whose courtesy I enjoyed the advantages of pursuing my studies at the U. S. Fish Commission Laboratory at Wood's Holl during the summer of 1889, where I was enabled to secure the material upon which the following observations were made. I am also indebted to Colonel Marshall McDonald, U. S. Commissioner of Fish and Fisheries, for various favors received through his department, and especially for many courtesies while

I was at the Fish Commission Laboratory, and for his kind co-operation in securing embryological material both at Gloucester and at Wood's Holl, Massachusetts.

II. Preliminary Account.

(*a*) *The Material.* — The material upon which the following observations are based is from Fundulus heteroclitus, an oviparous Cyprinodont, known in common parlance among fishermen as the "Short Minnow." The material was secured during the month of July, 1889, at Wood's Holl. The adult fishes of both sexes were taken with a seine along the shores of Buzzard's Bay, and confined in the aquaria of the hatchery at the Fish Commission station. At the proper time the ripe ova and sperm were taken by the process known as "stripping," and the ova were "artificially" fertilized and kept in running sea-water in a laboratory aquarium. From this supply of ova small quantities were taken at intervals up to the time of hatching, which varies from sixteen to eighteen days after fertilization, the temperature of the water being at an average of about 20° C.

The ova are submersal, remaining at the bottom of the aquarium, unless the current is strong enough to agitate the water sufficiently to raise them. They are covered with fine filaments, which are produced, according to Eigenmann ('90, pp. 129–132), by a membrane lying outside the zona radiata. The filaments of different eggs become entangled, and hold the eggs in clusters. The ova are about 2 mm. in diameter, with considerable variation in ova taken from different females. They are somewhat translucent, contain numerous oil globules, which are at first near the blastodisc, but are gradually carried over the yolk during the course of the development of the blastodisc. In Fundulus the yolk is not all absorbed until several days after hatching.

(*b*) *The Technique employed.* — The ova were killed at intervals increasing from one hour in the younger to eight hours in the older stages. The killing reagents used were Perenyi's fluid, Kleinenberg's picro-sulphuric mixture, and a solution of 0.25% osmic acid, followed by Whitman's modification of Merkel's fluid. The osmic material was washed in water, both before and after the use of Merkel's fluid, and all the material subsequent to the use of the killing reagent was carried through grades of alcohol to 90%. The material preserved with Perenyi's fluid has proved to be the most satisfactory, especially with the younger stages, but Kleinenberg's picro-sulphuric mixture is perhaps rather better for the more advanced stages. Both these reagents

may be successfully used without the removal of the egg-shell; but in the use of osmic acid it is necessary to remove the shell, in order to enable the reagent to penetrate with sufficient rapidity.

In staining, I have attained my best results from the use of Kleinenberg's hæmatoxylin *in toto* for 20 to 24 hours, and decoloring with 70% acidulated alcohol for about 2 to 4 hours. This statement applies to material preserved with Perenyi's fluid and Kleinenberg's mixture. With osmic material the best results in staining have been attained by the use of Czokor's cochineal for 10 to 12 hours. The embryos were removed from the yolk under the dissecting microscope, dehydrated, penetrated with clove or cedar oil, followed with paraffin at a temperature of about 55° C., imbedded in paraffin in the usual way, and sectioned with a Thoma or a Cambridge rocking microtome.

(*c*) *Variation in the Development of Fundulus.* — In Fundulus I have noted a very considerable individual variation in the progress of embryonic development. Inasmuch as the ova of several individuals were placed together in the same aquarium for fertilization, this variation could not be owing to differences of surroundings, but may be due to a difference in the stages of maturity of the ova from the different females. I do not believe that a delay in the fertilization of some of the eggs could be sufficient to account for the existing variation in development. The period of vitality of the free teleostean spermatozoön is not very accurately known, but it probably does not exceed *a few hours.* It seems to me quite certain that no possible delay in the fertilization of any of the ova could account for the great difference in the hatching period, which has been found to vary as much as forty-eight hours; and since this variation also exists at the point of hatching, it cannot be assumed that all the retarded embryos below the hatching period are imperfect and do not reach maturity.

It is very probable that ova which are removed from the ovary by the process of "stripping" may not have reached the highest degree of maturation, and it may be possible that such ova are yet capable of fertilization, but that when thus artificially fertilized the development is not as rapid as in case of fully matured ova.

Owing to this variation, the embryos preserved at the same time do not all show the same stage of development; hence, to ascertain the relative advancement of the individual embryos of the same age requires considerable study of certain structures, — e. g. the condition of the optic and auditory vesicles, the nephrostome, gill-clefts, etc., — which may be selected as a safe index to exact stages of development. It has

frequently occurred that, while seeking an embryo slightly more advanced than that just studied, one was found among *later* killings which represented a stage twelve to eighteen hours *younger*. This fact has vastly increased the task of finding a more or less complete series of successive stages.

III. — Summary of the Literature on the Development of Paired Fins in Fishes.

In this summary an attempt is made to trace the history of the observations which have led to our present knowledge of the development of the pectoral fins in fishes. Papers containing only purely theoretical and phylogenetic considerations upon the intensely interesting question of the origin of the vertebrate limbs are omitted, and also the observations which are based exclusively upon the morphological conditions of the adult forms. Hence, only such as are in the main embryological are referred to. Several papers are included which do not refer to fishes, but deal with the early development of the limbs in groups closely related to fishes. The earlier accounts of the fins by Rafinesque, Forchhammer, Rathke, von Baer, Lereboullet, and others, are not of much importance in considering the relation of the limb-buds to the germinal layers, and are consequently omitted.

(*a*) *Teleosts.* — Oellacher ('79, pp. 141–143), in a preliminary notice, which has not, to my knowledge, been followed by a more comprehensive communication upon the same subject, gives an account of the development of the paired fins in the Brook Trout. He maintains that the protovertebræ in the region of the pectoral fins grow out laterally into a mass of cells, which in cross section of the embryo gives the appearance of a triangular plate, lying directly upon the upper peritoneal layer, or somatopleure, and bounded by ectoderm above, the inner face of the triangle being continuous with the protovertebræ. This lateral mass of mesoderm becomes thinner in passing forward, backward, and outward, ending in a distinct margin, while it is thickest at its base, where it is continuous with the protovertebræ. Later, a change takes place in the contour of these plates, so that, instead of being thickest at their inner limit, where they are in connection with the protovertebræ, they are now thickest in a region farther from the axis of the embryo, and in cross sections of the latter present the outline of a triangle, with a slightly acute angle above, a sharply acute angle outwards, the point of the inner angle being in continuity with the protovertebræ.

Oellacher says nothing concerning the histological character of these structures, and gives no drawings. He makes no mention of the modification of the ectoderm in the region of the pectoral fin, and believes the ectodermal fold to be absent in these fins; but he observed it in case of the pelvic and dorsal fins, and upon this difference he raises the question as to the different morphological signification of the pectoral and pelvic fins from the standpoint of their genesis. Oellacher was the first observer to trace the origin of the paired fins from the mesoderm, but it is evident that he failed to see the primary source of the mesoderm of the limb-bud, and did not understand the secondary relation between the pectoral plate and the protovertebræ.

'Swirski ('80, p. 15) has studied the limb-buds of the young fry of the Pike, and gives an account of their later structure and the development of the rudimentary skeletal parts. His description of the appearance of the mesoderm in cross sections of the pectoral fin of a young Pike, a day old, substantially agrees with that given by Oellacher ('79) for the Brook Trout. He also describes briefly the cells of the ectodermal fold, stating that the ectoderm in the region of the fold consists of beautiful large, cubical cells, with fine-grained nuclei and dark-grained protoplasm. 'Swirski notes that the ectodermal fold develops independently of the mesoderm, and is not continuous along the side to the region of the ventrals; that it is present in the case of the pectoral fins is a fact which Oellacher had overlooked. 'Swirski does not, however, note any observations upon the earlier development of the limb-bud, or upon the source of its mesodermal elements, and regards the ectodermal fold as the beginning of the pectoral fin.

Emery ('83, p. 338) first directed attention to the homogeneous stratum developed in the fin-fold of embryos of Bony Fishes. He studied the larvæ of Fierasfer, Belone acus, and Lophius, and regards the substance between the ectodermal layers of the fin-fold as mesenchymatic; this substance may originate as a secretion partly by ectoderm and partly by mesoderm; and he believes that it may be comparable to the gelatinous substance of the umbrella of Medusæ. His observations were however made upon the folds of the unpaired fins.

Kingsley and Conn ('83, p. 210) did not see the earlier stages in the development of the pectoral fins in the Cunner, Ctenolabrus cœruleus. The earliest condition noted by them was that of the ectodermal fin-fold just prior to the time of hatching. They say, "The fins, which are first seen in an egg about as far advanced as Figure 51, arise in the Cunner as a simple outgrowth, and not as a continuous lateral fold, as is found in many forms."

Prince ('86, p. 697) regards the pectorals of Osseous Fishes as at the beginning *ectodermal* in origin. He states that "they are differentiations of a continuous lateral expansion of *epiblast*, passing along each side of the trunk, and are formed by the folding of this epiblastic layer upon itself at the point where the fins appear. Each fin consists, therefore, of two epiblastic lamellæ (separated by a fissure), lying flat upon the vitellus, and continuous with the extra-embryonic blastodermic membrane." The participation of the mesoderm is presumably a secondary process. Concerning the origin of the mesodermal cells which are introduced into the fin-fold, Prince says, "They seem to be derived from the 'intermediate cell-mass' in close proximity to the Wolffian ducts."

Ziegler ('87, p. 619), in his excellent paper on the origin of the blood and the vascular system in the embryonal Teleost, has touched upon the source of the mesodermal elements of the pectoral fin. He has observed in the embryos of the Salmon and Pike, in stages immediately following the closure of the blastopore, a layer of cells lying upon the somatopleure just back of the gill region. This layer of cells he regards as the beginning of the pectoral fin. Anteriorly, it is intimately connected with the mesoderm of the head; it extends laterally in front of the first protovertebra, and obliquely backwards upon the somatopleure, gradually losing its identity in the latter. Ziegler also states that the development of the pectoral fin is accompanied by the formation of a lateral longitudinal fold of the ectoderm, but does not give details.

Ryder regards the modification of the ectoderm as the earliest differentiation in the development of the pectoral fins in Teleosts, and therefore the differentiation of mesoderm as a *secondary* process. His observations have been very extensive, and include representatives of various groups of Osseous Fishes. He states ('86[a], p. 24) that in the stickleback, Apeltes quadracus, "immediately behind the auditory vesicles, and shortly after their invagination, the rudiments of the breast fins appear as a pair of low longitudinal folds." In the common Shad, Clupea sapidissima ('86[a], p. 43), the modification of the ectoderm is the earliest process noted in the development of the pectorals. It is implied ('82, p. 293) that in the Silver Gar, Belone longirostris, substantially the same condition exists. Many of Ryder's observations are apparently based upon surface views only. He ('84, p. 65) states that in the evolution of the pectoral fin of the Cod, Gadus morrhua, the first appearance is "a slight longitudinal elevation of the skin on either

side of the body of the embryo, a little way behind the auditory vesicles. . . . At the very first, it appears to be merely a dermal fold, and, in some forms, a layer of cells extends out underneath it from the sides of the body, but does not ascend into it." He adds: "In some species I am *quite well assured* that there is at an early period a mesodermal tract or plate of cells developed just behind the auditory vesicle, just outside the muscle-plates of this region, on either side, which may be regarded as the source of the mesodermal cells which are carried up into the pectoral fin-fold. This is developed at the time of the closure of the blastoderm, and these lateral mesodermal tracts may be called the pectoral plates." In later stages of development, Ryder observes that mesodermal cells make their appearance at the base of the ectodermal fin-fold, and enter the basal part of this fold. Referring to the Carp, Gambusia patruelis, he ('85, p. 153) states that the muscles of the pectoral fins "are probably derived, as in Elasmobranchs, from buds given off by the muscular segments above the rudiment of the girdle"; but the evidence from which this inference is drawn he does not state. Ryder ('86, pp. 1010, 1018) has studied the development of the fin-rays in the lateral ectodermal fin-fold, and has written upon theoretical considerations concerning the evolution of the fins in fishes.

M'Intosh and E. E. Prince ('90, pp. 800–803) have assumed that the paired fins in Bony Fishes are of ectodermal origin, and begin as horizontal ridges, in accordance with Balfour's theory of a primitive lateral fin. They regard the lateral margin of the blastoderm, at a stage in which the blastopore is not yet closed and the embryonic thickening has merely begun, as the first trace in the development of the pectoral fins. This lateral margin of the blastodermic swelling is described as an "alar expansion" along each side of the embryo, and "consists of epiblast and hypoblast resting upon the stratum of periblast below" (p. 800). From these lateral wing-like expansions of ectoderm and entoderm, between which apparently no mesoderm extends, the fins are developed. The views of these authors may be more fully comprehended from the following quotation (p. 801): "A pair of lateral, horizontal alæ (*al.*), indeed, stretch along the whole trunk, — from the pectoral to the post-mesenteric region. It is in reality the elongated and narrowed blastodermic scutum (Plate XXVIII. Fig. 5), and extends in front and behind the two points mentioned, though it is there thinner and hardly distinguishable. In Plate III. Fig. 19, such a pair of lateral horizontal fin expansions are present, extending from the trunk region proper, and their limits are very definite when viewed from above. Just as in the

case of the median vertical fins, certain areas in these horizontal alæ become defined as special fin regions by a visible thickening, apparently from the folding under of the epiblast. Thus two flattened oval pads, consisting of a double epiblastic fold like the double median fin-fold, are disengaged from the rest of the alar expanse. Before and behind this pair of pads the lateral membrane thins away and atrophies, while the special portions continue to increase in density as a pair of pectoral limbs." Into these "fin-pads," or limb-buds, the mesoderm later enters, separating the two ectodermal layers of the fold. The source of the mesoderm of the pectoral fin is referred to "a mass of cells in which the Wolffian ducts lie and out of which they are developed" (p. 802). This conclusion leads the authors to the following speculations concerning the relation and evolution of the Wolffian ducts and the mesoderm of the pectoral fins: "If these ducts, as appears to be the case, arise as lateral ridges or diverticula of the somatopleure, then the mesoblast cells of the fins must be pronounced somatopleuric. But no ridge of somatopleuric cells comparable to the Wolffian ridges of higher forms has been recognized in fishes, and we must regard this mesoblast as indifferent, and forming an 'intermediate cell-mass' adjacent to the excretory system." The observations by M'Intosh and Prince refer to various Bony Fishes, including Gadus morrhua, Molva vulgaris, Trigla gurnardus, Cottus scorpius, etc. The statement is made (note, p. 801) that in all forms studied at the St. Andrews Marine Station the pectoral fins arise out of the lateral extensions of ectoderm and entoderm.

(*b*) *Elasmobranchs, etc.* — Balfour ('78, pp. 101, 102), as is well known, was one of the first to advocate the theory that the limbs of Vertebrates are remnants of a continuous lateral fin. This view of the phylogeny of the Vertebrate limb led him to a careful study of the development of the paired fins in the ontogeny of several types of Elasmobranch Fishes, including Torpedo, Pristiurus, and Scyllium. A brief summary of Balfour's extensive and detailed account may include the following conditions in the early development of the paired fins: (1) a continuous lateral thickening, or ridge of ectoderm, extending from the head to the level of the anus; (2) between the regions of the pectoral and pelvic fins this ridge of modified ectoderm may be so slight as to be observable only upon a careful examination of sections; (3) special developments of this lateral ridge — one opposite the anterior end of the segmental duct, the other just in front of the anus — constitute respectively the rudiments of the pectoral and pelvic fins; (4) the rudiments of the an-

terior pair of fins develop much more rapidly than those of the posterior pair; (5) the connecting ridge of ectoderm between the rudiments of the paired fins disappears; (6) these ectodermal rudiments develop into elongated projecting folds; (7) the mesoderm at the base of these folds becomes closely packed, and forms a slight projection; (8) the cells of *both* layers of the ectoderm, judging from Balfour's drawings ('78, Plate XI. Fig. 9, and Plate XII. Fig. 1), take on a columnar form in the regions of the fin-folds.

It is evident that Balfour regarded the primary modification of the ectoderm into a thickening or ridge as the earliest step in the development of the paired fin in Elasmobranchs, and the modification of the mesoderm as a *secondary* condition, and *coincident* with the formation of a distinct fold by the ectoderm. Balfour ('81, Vol. II. p. 500) also held the same view concerning the similar modification of the ectoderm in other groups of fishes.

During the course of the further development, the mesoderm passes into the fold of ectoderm, and assumes the appearance of a closely packed mass of indifferent cells, which, together with its ectodermal covering, now presenting a somewhat rounded contour, constitutes what is known as the primitive "limb-bud." Subsequently the muscle-plates grow in a ventral direction to the level of the limb-bud, and several of them turn slightly outward at their distal ends, and give off small masses of cells, the myotome-buds, which pass into the blastema of the limb-bud, where they soon lose their former distinctness, but presumably constitute the source of the musculature of the limb. The muscle-plates, after having given off the myotome-buds, lose all trace of this modification, and continue their growth in the ventral direction.

Balfour did not determine the real character of the myotome-buds, or the number for each myotome; nor did he trace them to their subsequent fate. This, however, was accomplished by Dohrn a few years later.

Kölliker ('79, p. 805) held that the muscle-plates as such in no case grew into the limb-buds, and that the view of an independent formation of the limb-muscles is provisionally quite as correct as the other view, although Remak ('50–'55) had shown that in the Rabbit the muscle-plates extended at least a short distance into the limb-bud.

Dohrn ('84, p. 161) did not investigate the primary source of the mesoderm which passes into the ectodermal fin-fold, but, accepting Balfour's account of the origin of the limb-bud, began his studies with the secondary contributions of the mesodermal elements from the muscle-plates. Dohrn pointed out that in the region of the pectoral fin, in the

embryo of Pristiurus, each myotome gives off at its ventral margin two small buds, one from its anterior and the other from its posterior edge. These buds, after losing their connection with the myotome, lengthen in a dorso-ventral direction, and then divide parallel to the surface of the body, thus forming four secondary cell-masses for each myotome, — two dorsal, or outer, and two ventral, or inner. These masses of indifferent myotomic elements pass into the limb-bud, and ultimately assume positions which make them here also respectively dorsal and ventral, and constitute the source of the entire musculature of the limb. Dohrn was, however, unable to determine the exact number of myotomes which thus contribute elements to the pectoral limb-bud, nor could he ascertain which myotome is the most anterior, or which the most posterior, to give off buds to the pectoral fin.

Ziegler ('88, pp. 388–390) has briefly described the source of the mesoderm of the pectoral fins in Elasmobranchs. In stages *H* and *J* (of Balfour, '78) there is produced upon the somatopleure, chiefly by cell proliferation, a layer of formative tissue, which extends caudad through the pectoral region. This process is accompanied by an upheaval of the ectoderm, and constitutes the beginning of the formation of the fore limb. Ziegler believes that this formative tissue (Bildungsgewebe) of the pectoral is continuous with the sclerotome, passing over between the segmental tubules. He has also pointed out that the dorsal ends of the myotomes at first give off to the dorsal fin formative tissue as single-cell strands, and later the myotome buds observed by Dohrn and Paul Mayer ('86). It is to be inferred, in the absence of any statement upon this point, that similar cell strands have not been observed on the ventral sides of the myotomes passing to the pectoral fins.

Beard ('89, p. 114) has observed the contribution of muscle-buds from the myotomes in Lepidosteus osseus. He says: "The somites become much elongated, and their ends are constricted off as buds to form the musculature of the paired and unpaired limbs. Each end of each somite constricts off a single bud, which only divides into two at a stage later than that of the twenty-first day. The posterior pair of fins begin to develop only towards the end of the third week, and the muscle-buds of the unpaired fins remain in an embryonic condition beyond this period."

Van Bemmelen ('89, p. 240) has studied the limb-buds of the Lizard, and has pointed out the presence of myotome buds. In a stage in which five gill-pouches are developed, the myotomes back of the auditory vesi-

cle, from the fifth to the thirteenth inclusive, contract at their ventral ends into cell-strands (Zellenstrange), which extend ventrally and terminate blindly in an indifferent cell-mass, the limb-bud. Van Bemmelen is convinced that these cell-strands, or myotome-buds, give rise to the musculature of the fore limbs, but he is unable to determine the further process by which this is effected. Similar contributions of mesoderm are made by the myotomes in the region of the hind limbs. Each myotome is said to develop only one bud, whose cells at its ventral end stain more deeply than the surrounding cells of the embryonal tissue, and later are entirely lost in the tissue of the limb-bud.

IV. The Axial and Parietal Mesoderm.

(*a*) *Formation of the Primitive Layers, and the Differentiation of Protovertebræ and Lateral Plates.* — With the temperature of the water at an average of 20° C., the blastopore in the embryo of Fundulus heteroclitus closes during the period between forty-six and forty-eight hours after fertilization of the ovum. If in an embryo in which the blastopore is not yet closed, a transverse section be taken through the region indicated by the line at *5* in Figure 1 (Plate I.), the condition of the primitive embryonic layers will be shown. From such a section (Fig. 5) it can be observed that the spinal cord (*cd. sp.*) is not yet fully formed, and that the superficial layer of the ectoderm (*ec'drm.*) is not involved to form later the medullary canal (*can. med.*, Plate V. Fig. 30); hence in this particular the development of the spinal cord in Fundulus differs from that in Amphibians, Elasmobranchs, and, according to recorded observations, in some Bony Fishes.

The endoderm (*en'drm.*, Fig. 5) is already clearly differentiated, and lies directly upon the yolk, extending as a single-cell layer from the keel laterally to the ectoderm; hence it comes in contact with the ectoderm both in the axial region of the embryo, ventrad of the keel, and also at its extreme parietal margin.

The mesoderm appears as a band of cells between the ectoderm and endoderm, extending longitudinally along either side of the embryonic keel. In a transverse section (*ms'drm.*, Fig. 5) the mesoderm has the appearance of a layer of cells which is somewhat thickened in the middle, while it gradually becomes thinner toward the axial and lateral margins. In a stage of fifty-two hours (Fig. 2) the embryo has become relatively much elongated, the optic vesicles (*vs. opt.*) are already quite prominent, Kupffer's vesicle (*vs. K.*) can be distinctly observed in a

clove-oil preparation, and the chorda is formed as far forward as the pectoral region, where it is now closing in, but is not yet distinct from the endoderm (*cd.*, Fig. 6). The endodermal cells in the parietal regions are rapidly moving in the direction of the embryonic axis, but no trace of the lateral infolding to form the tube of the intestine is as yet discernible.

The condition of the mesoderm may be observed in a transverse section (*ms'drm.*, Fig. 6) of an embryo perhaps a little more advanced than the one represented by Figure 2, taken from the region indicated by the line at *6* in Figure 2. In this region the mesoderm appears as a solid mass of cells which, in transverse section, has a triangular contour, ending in blunt angles at the dorsal and ventral limits of its axial boundary, and tapering laterally into a single-cell layer, which now extends beyond the lateral margin of the endoderm, the latter having shifted towards the axis of the embryo to form the chorda, as already noted. It follows, therefore, that the distal margins of the lateral mesodermal plates lie directly upon the yolk. The differentiation of the mesoderm into protovertebræ and lateral plates has evidently not yet begun at this stage, and no trace of a split in the mesoderm to form the somatopleure and splanchnopleure can be seen.[1]

The most anterior protovertebra is formed immediately back of the auditory vesicle; in fact, it at first extends rather forward and below the posterior limit of the auditory vesicle (Fig. 8, *pr'vr. 1*). It is interesting to note that later a considerable space intervenes between the latter and the most anterior protovertebra. (Compare Fig. 21, Plate III.) This intervening space is equal to the length of at least one protovertebra, and still later (Plate I. Fig. 8[a]) to about two protovertebræ. There is some uncertainty as to the process by which the increase in this space is produced. There are at least four possible methods of increasing it: first, there might be an actual shifting of the anterior protovertebra caudad; secondly, a shifting of the auditory vesicle cephalad is conceivable; but I believe that neither of these is realized; thirdly, there might be a *relative* shifting of these structures in the respective directions named, caused by a voluminous cell proliferation of the head-mesoderm (*ms'drm. cap.*, Fig. 21, Plate III.) between the auditory vesicle and the first protovertebra, causing an elongation of the embryonic axis in this region; fourthly, the first — and perhaps also the second — protovertebra may degenerate, remaining only as

[1] I have used the words *somatopleure* and *splanchnopleure* in the sense of somatic and splanchnic mesoderm respectively.

head-mesoderm, and thus, through the obliteration of the first two protovertebræ, the original third would now be recognized as the most anterior. The mass of the obliterated protovertebræ, which, however, has not been decreased in volume, but whose contour as protovertebræ has disappeared, is now recognized as head-mesoderm, and has thus augmented the space intervening between the auditory vesicle and the now most anterior (original third) protovertebra. It is highly probable that the last two processes enumerated, namely, the proliferation of head-mesoderm and the degeneration of protovertebræ, combine to produce the apparent removal of the first protovertebra from the auditory vesicle, or the increase in the space intervening between these structures. It is certain, at any rate, that there is at this time an active cell proliferation in the head-mesoderm of this region, and that the first and second protovertebræ become less distinct and more or less imperfect subsequent to their early formation.

(*b*) *Topography of the Embryo.* — For convenience in description and reference to the different regions of the embryo, I have adopted the following general divisions in the topography of later stages : —

(1) *The head region* includes all of the embryo from its anterior end to the posterior limit of the auditory vesicle.

(2) *The pectoral region* includes all from the posterior limit of the auditory vesicle to the nephrostome.

(3) *The abdominal region* embraces all of the embryo included between the nephrostome and the point of the future anus.

(4) *The caudal region* includes all back of the anus.

This classification is slightly different from that adopted by Ziegler ('87, p. 643). The boundary between the head region and pectoral region cannot be definitely fixed, inasmuch as the position of the first protovertebra is changeable. Although not embraced in the region of the *head* by this classification, the axial mesoderm between the auditory vesicle and the first protovertebra is designated as "head-mesoderm." As will be seen later, this region is probably involved in the origin of the pectoral fin.

(*c*) *Differentiation and early Development of the Mesoderm in the Pectoral Region.* — The changes which take place in the pectoral region during the earlier embryonic stages are of special importance in tracing the exact topography of the mesoderm, and the necessity of a reliable starting point in the topography will be apparent in subsequent considerations. The differentiation of the mesoderm into protovertebræ can be readily traced from the third or fourth protovertebra into the

caudal region. In an embryo of about fifty-six hours (Fig. 8), five protovertebræ are distinctly formed, and the mesoderm back of the fifth protovertebra as far as the caudal region still consists of a compact plate of cells (*ms'drm. ax.*), whose boundary is easily distinguished from the ectoderm above and the endoderm below. The nuclei in the region of the axial mesoderm are undergoing rapid division as shown by the abundance of their various karyokinetic conditions. The protovertebræ which are already formed in an embryo at the beginning of the third day, are somewhat irregular in outline and vary considerably in size. The first (Fig. 8, *pr'vr. 1*) is considerably larger in its antero-posterior dimensions than any one of the other four. This condition I have observed in several instances, but apparently it does not always obtain ; for in two embryos of the same age, but perhaps slightly more advanced than that of Figure 8, I find the first protovertebra not only shorter in its antero-posterior direction, but also decidedly more irregular in outline than the others in the same embryo. Possibly the superior size of the first protovertebra in an earlier stage may be the rule, but this condition must be very transitory ; so that, owing to individual variation, embryos of the same age, but slightly more advanced, may show the inferior size and imperfect contour in the first protovertebra as a secondary condition. The axial mesoderm in front of the first protovertebra (Fig. 8) extends forward under the auditory vesicle, and its cells are disposed in two more or less distinct layers, the boundary between which extends outward, i. e. laterally from the axis of the embryo, where it is continuous with a similar boundary (Fig. 7, *cœl.*) between the layers of the lateral plate in the trunk region.

The changes in the development of the mesoderm in the pectoral region can be most profitably studied from transverse serial sections. The differentiation of the protovertebræ and lateral layers, and the formation of the cœlomic split, are intimately involved, and must therefore be traced conjointly in the pectoral region.

In the anterior region of the auditory vesicle, the axial mesoderm is reduced to its minimum volume. A transverse section through this region from an embryo of about seventy-one hours shows (Plate II. Fig. 9) that the mesoderm consists of two portions, the axial and the lateral; the latter is composed of two single-cell layers, somatopleure and splanchnopleure (*so'plu.*, *spl'plu.*), which in this region form the boundaries of the pericardial cavity (*cav. pi'cr.*). These layers are continuous with each other in their proximal (axial) region, but separate at their distal (lateral) margins, the splanchnopleure extending farther

laterally than the somatopleure, and the margins of both lying close against the ectoderm.

The axial mesoderm, or protovertebral part (*ms'drm.*), consists in this region of only a few cells. These lie between the proximal portion of the lateral layers and the brain (*en'c.*), and are bounded dorsally by the incipient auditory vesicle (*vs. au.'*) and ventrally by the endoderm (*en'drm.*). The axial mesoderm may be traced as head-mesoderm from this point caudad into a region where it is more or less distinctly segmented into protovertebræ (Figs. 12–14).

In the middle region of the auditory vesicle (Fig. 10), the axial mesoderm becomes more voluminous and presses the pericardial cavity farther away from the axis of the embryo. The lateral layers are not separated from the axial mesoderm (compare Fig. 9), and their distal margins are united. The most anterior protovertebra in this stage (Fig. 11) is not wholly cut off from the lateral mesodermal layers. The lumen of the body cavity (*cœl.*) can be traced cephalad into the pericardial cavity, and extends into the interior of the protovertebra as well as laterally between the somatopleuric and splanchnopleuric layers. The dorsal boundary of this lumen is a single-cell layer, while the layer on its ventral side is of variable thickness; in its proximal or protovertebral region it is about three cells in thickness, while in the middle it is two cells and at its distal margin only one cell thick, thus giving in cross section a cuneiform outline; it represents a portion of the protovertebra and the undifferentiated splanchnopleure. The section drawn in Figure 12 is the third section (about $22\frac{1}{2}$ μ) back of Figure 11, and represents the posterior part of the corresponding (first) protovertebra on the opposite side of the embryo.[1] In this region of the protovertebra, the dorsal contour is more rounded, and the body cavity does not extend into it; the nuclei outline a boundary between the protovertebra and the lateral plates more distinctly than in the anterior region of the protovertebra (compare Fig. 11).

The second protovertebra is cut off from the surrounding mesoderm more completely than the first. A cross section from its middle region (Fig. 13) shows a more or less distinct boundary separating it from the lateral layers. It has a sharply rounded contour at its dorsal limit, and the nuclei show a tendency to assume a peripheral position. The body

[1] The embryo being cut exactly in the transverse plane, and the conditions in the mesoderm on both sides of the axis being identical, I have taken my drawings alternately from the right and left sides (Plate II), in order to economize space in the arrangement of the figures on the Plate.

cavity is less marked than in the first protovertebra, but the cells are quite uniformly arranged into the two mesodermal layers. It may be noted, in passing, that while the pericardial and body cavities are continuous at an early stage, they are not developed simultaneously; that the pericardial cavity is well advanced before any trace of the corresponding split, or body cavity, occurs in the pectoral region.

All the protovertebræ caudad from the second are distinctly cut off from the lateral layers. In the region of the fifth (Fig. 14) and for some distance caudad from it, the lateral layers (*so'plu.*, *spl'plu.*) end more abruptly at their distal margins, while in the proximal region there is a tendency on the part of the cells — due apparently to rapid proliferation — to become aggregated, and thus to render somewhat obscure the boundary between the two lateral layers; meanwhile the proximal margin of the lateral mesoderm (Fig. 14) shifts its position ventrad along the side of the protovertebræ.

Still farther back in the region of the sixth or seventh protovertebra, the proximal region of the lateral mesoderm is distinctly cut off from the more lateral portion (Fig. 15, *cl-mo. i'm.'*); as will be seen later, it has a very interesting and significant fate. At this stage the nuclei of the cells of the complete protovertebra are clearly arranged in a peripheral position (Fig. 14, *pr'vr.*). Rarely nuclei are observed in the interior. If, however, the plane of the section is not parallel with the transverse dorso-ventral plane of the protovertebra, or chances to pass through its anterior or posterior wall, the section shows nuclei which are apparently in the middle of the protovertebra. These are in many instances the nuclei of cells forming its anterior or posterior wall; but in other cases they do not represent cells in the peripheral walls, for the condition in which all the cells have this position is very transitory. Immediately following this stage (Plate III. Figs. 17, 18), nuclei are observed which are unquestionably in the middle of the protovertebra. The nuclei which are thus found in the interior of the protovertebra no doubt have their origin in the peripheral cells, and usually are undergoing division rapidly at this stage. Not only do the peripheral cells thus contribute to the interior of the protovertebra, but also to the increase in the superficial extent of the peripheral wall, and in many cases it is not difficult to determine from the direction of the nuclear division whether the contribution is to the wall or to the interior. In Figure 18 (Plate III.), on the left side of the embryo (right in the figure) in the dorsal region of the protovertebra, is an example of nuclear division (*nl.'*), in which one of the daughter cells is destined to pass into the interior; in the proto-

vertebra shown in Figure 27 (Plate IV.), the two pairs of nuclei in the upper region bounding the spinal cord, which have just undergone division (*nl.''*), are destined to increase the periphery of the protovertebra; and in Figure 17 (Plate III.) is an example of the proliferation of cells in the interior of the protovertebra.

These three examples are the same in character, and tend to the same general purpose, viz. the enlargement of the protovertebra itself; but there is also a cell proliferation going on in its ventral region which has a purpose foreign to the augmentation of the protovertebra, for here the histological elements experience a very different fate. In the ventral region near the chorda a rapid cell proliferation (Plate III. Fig. 18, *nl.''*) is going on. Some of the cells which originate here pass ventrad, and take a position immediately under the chorda (*nl.**), and I believe it very probable that they are concerned in the formation of the aorta.

In this stage the lateral mesodermic layers are more distinctly separated from each other, leaving between them a relatively larger body cavity (compare Fig. 17, Plate III., and Fig. 13, Plate II.), and in the anterior region of the trunk they are undergoing rapid development. The process of shifting toward the median plane along the ventral side of the protovertebræ, the beginning of which has already been noted (p. 107), has perceptibly advanced. This process does not begin in the pectoral region and proceed backward, as might be inferred; but is at first more pronounced back of the pectoral region, and only later takes place as far forward as this. This fact will be evident upon a glance at the series of drawings from a younger stage (Plate II. Figs. 11–15).

In an embryo of seventy-one hours the head-mesoderm (Plate IV. Fig. 23) in the region of the auditory vesicle consists of only a few cells, whose nuclei do not assume any definite arrangement. This condition is probably due, in part, to pressure upon the original mass of mesodermic cells by the ectoderm and endoderm. The latter, constituting the beginning of the gill-clefts (*fs. brn.*, Fig. 23), presses upward, while the former, constituting the beginning of the auditory vesicle (*vs. au.*, Fig. 23), presses downward, thus confining the mesodermic cells within very narrow limits. The nuclei of the head-mesoderm are, however, readily distinguished from the surrounding ones of ectodermic and endodermic origin. In the region of the gill-clefts the head-mesoderm is completely cut off from the part which represents the somatopleure and splanchnopleure (Fig. 23), and the latter (*so'plu.*, *spl'plu.*) are relatively thin layers, bounding the pericardial cavity. In this stage of development the distal end of the gill-cleft (*fs. brn.*) has apparently nearly broken through

to the exterior, the invagination of the ectoderm (*ec'drm.'*) having almost reached the endoderm; but the fourth gill-cleft (*brs. brn.*) has not yet advanced so far, as is shown by a section (Fig. 24) from the same embryo, but 30 μ farther back; hence the head-mesoderm is now more voluminous in this region than in the region of the third gill-cleft, and more than it will be here in later stages. It is evident that, as the fourth cleft develops, it will invade the region now occupied by this mass of head-mesoderm, hence the latter must migrate. But since the gill-clefts develop from before backward, and since the third cleft has already so far developed as to occupy together with the auditory vesicle practically all the space (Plate IV. Fig. 23), there is no possibility of that part of the head-mesoderm which is now back of the third cleft migrating or being pressed forward in order to yield its space to the intruding fourth gill-cleft. Being thus guarded in front and on its ventral boundary by the endoderm, on its axial boundary by the spinal cord, and on its lateral by the pericardial cavity, the only possible course left for this mesoderm is to pass in a posterior direction toward the pectoral region. Furthermore, the endodermal evaginations forming the gill-clefts do not lie in an exactly transverse dorso-ventral plane, but extend obliquely from below upward and backward as well as outward and backward; hence, as this evagination proceeds, there is a natural tendency to press the head-mesoderm in advance of it in the same direction. It may be safe, therefore, to base upon these facts the inference that the position of the gill-clefts, and the order and direction of their development, tend to cause the head-mesoderm of the branchial region to pass in a posterior and lateral direction.

The relation of the head-mesoderm to the axial mesoderm in the pectoral region may be better understood by sectioning different parts of a single embryo in planes perpendicular to each other. An embryo in which the distal tip of the fourth gill-cleft (Plate III. Fig. 16, *brs. brn.*) extends about midway through the region of the head-mesoderm (*ms'drm. cap.*) toward the ectodermic invagination (*ec'drm.'*), is sectioned transversely through the branchial region from the anterior end of the embryo to the plane of the fourth cleft, represented by the drawing, Figure 16. The remaining part of the embryo is then re-oriented upon the microtome, and sectioned in a longitudinal (sagittal) direction, beginning on the left side of the embryo and proceeding toward the axis. Figure 16 represents the anterior face of the last section of the transverse series from an embryo treated in this way, and Figures 19–21 show the series of sagittal sections in the same embryo. The vertical parallel lines *19*, *20*, *21*, through Figure 16, indicate the direction and the relative

positions of the planes of the sagittal sections shown in Figures 19–21. The relation between the head-mesoderm and the splanchnopleure in the pectoral region is represented in Figure 19. This section is taken from a region too far from the axis of the embryo to show any trace of the protovertebræ, nor is the fourth gill-pocket yet developed far enough in a lateral direction to reach this vertical plane; but the auditory vesicle (*vs. au.*, Fig. 19), which extends farther laterally (compare Fig. 19 with Figs. 16 and 24), is shown in the section. Hence the head-mesoderm (Fig. 19, *ms'drm.*), as represented in this section, may be said to extend back of the auditory vesicle and laterally of the fourth gill-pocket, and to converge at its posterior margin into the single-cell layer (*so'plu.*) of the somatopleure. The ventral surface of the head-mesoderm may be regarded morphologically equivalent to the somatopleure.

In Figure 20, drawn from a section about $22\frac{1}{2}$ μ nearer the axis of the embryo than Figure 19, the fourth gill-pocket is intersected, and also the distal face of the first protovertebra. Here the head-mesoderm is represented by a voluminous mass of cells which abut upon the anterior boundary of the first protovertebra (*pr'vr. 1*). In the next section (Fig. 21), whose plane lies still nearer the axis of the embryo, the head-mesoderm (*ms'drm.*) passes back and fuses with the first protovertebra, no boundary between the two being distinguishable. From this double series of sections the close relation existing between head-mesoderm, protovertebræ, and somatopleure must be evident.

I shall now consider the changes taking place in the two parietal layers during slightly older stages; these present three principal features: (1) their shifting in a median direction along the ventral surface of the protovertebræ; (2) the contribution of elements from their proximal region; and (3) the modification of the somatopleure in the formation of the beginning of the pectoral fin. But these changes, as in case of those involving the head-mesoderm, are taking place at the same time, and hence must be traced conjointly. The first two processes may be considered under the head of "intermediate cell-mass."

V. Intermediate Cell-mass.

(*a.*) *Brief Review of the Literature.* — The term "intermediate cell-mass" (Mittelplatte) was originally applied by Waldeyer ('69) to the mass of mesodermal cells between the protovertebræ and lateral plates in the Chick. The intermediate cell-mass in Birds is so well known that it is unnecessary to review its morphology in detail; suffice to say that

it appears immediately subsequent to the formation of the protovertebræ, e. g., in case of the Duck, as a band of mesodermal cells extending lengthwise of the embryo, between the protovertebræ and the lateral layers, somatopleure and splanchnopleure; that at first it remains in histological connection with the protovertebræ on the one side, and with the lateral layers on the other; that in later stages, as shown by Sedgwick ('80), the intermediate cell-mass is at intervals entirely cut off from relation with the lateral layers, while at alternating intervals it remains continuous with them and is penetrated by the body cavity; and that *subsequently* the structure is *wholly* disconnected from the lateral mesodermic layers, and constitutes what has been designated the "Wolffian blastema." These three steps in the process of development of the intermediate cell-mass in the Duck are represented in the Chick, according to Sedgwick's ('80) account, *only* in the anterior region of the embryo, to about the twentieth somite; while posterior to this region the intermediate cell-mass is from the beginning independent of the lateral mesoderm, thus presenting, apparently, an abbreviation of the process which takes place in the anterior part of the trunk.

The expression "intermediate cell-mass" is also applied to the homologous structure in Elasmobranchs. According to Balfour ('78, pp. 108, 109, 127, 128), in Pristiurus and Torpedo at the time when the third visceral cleft appears, the intermediate cell-mass arises as the result of a fusion of the somatopleure and splanchnopleure at about the level of the dorsal aorta, and immediately above the dorsal limit of the true body cavity. The mass of cells involved in this fusion Balfour regards as homologous to Waldeyer's "intermediate cell-mass" in the Chick. He does not state how far forward in the trunk this fusion of the mesodermal layers extends, but points out that from it the urinogenital system is developed, and shows that the first trace in the development of this system is the beginning of the segmental duct, which appears as a solid knob in the region of the fifth protovertebra, and grows backward along the inner surface of the ectoderm as a solid rod of cells.

An homologous structure is also present in Lacertilia. The accounts of the intermediate cell-mass in the Lizard by different observers agree in general, but differ somewhat in their details, and especially concerning its fate. As shown by Braun ('77) and Weldon ('83), it is present in the Lizard from the beginning of the segmentation of the mesoderm, and is connected both with the protovertebræ and the lateral mesodermic layers. According to Weldon's account, in an embryo of Lacerta muralis at a stage in which eleven protovertebræ are formed, there

are developed in the intermediate cell-mass, which previously appeared as a continuous solid mass of cells, a series of circular cavities, each opposite a protovertebra. The cavities thus formed in the intermediate cell-mass are the "segmental vesicles" described by Rathke ('33) and later observers. Weldon has shown that the segmental vesicles are not evaginations of the peritoneal epithelium, and do not form the Wolffian duct, as supposed by Braun, but that the latter structure is developed a little later and in a more peripheral or lateral region of the intermediate cell-mass, — indeed, from the lateral walls of the segmental vesicles. Other observers, however, differ in their views concerning the details in the formation of the Wolffian duct, and I do not propose to enter upon the discussion of this interesting subject. It is sufficient for my purpose to recognize the presence of the intermediate cell-mass in Lacertilia, and to note the fact that in its origin and fate it resembles very strongly the intermediate cell-mass in Birds and Elasmobranchs.

In Teleosts there is also present a structure very similar to the intermediate cell-mass of Birds, Reptiles, and Elasmobranchs, whose homology with the intermediate cell-mass has, however, been questioned by Ziegler ('87, p. 645). Oellacher ('73, pp. 76, 77, 102) was the first to describe this structure in Bony Fishes, and to adopt for it the name "intermediate cell-mass." According to his observations, in the Brook Trout, at the stage in which the vertebræ are forming, there remains between the lateral plates and protovertebræ a band of undifferentiated mesoderm, which later moves medianward, and meets its fellow from the opposite side, uniting with it under the chorda. Ziegler ('82 and '87) and Wenckebach ('84 and '86) have since observed this structure in the Salmon, Trout, and Pike. The intermediate cell-mass in Salmo salar is formed, according to Ziegler's ('82) account, at the time when the protovertebræ are cut off, which takes place on the thirteenth day, and after this process it remains as an unsegmented band of cells, extending throughout the whole length of the trunk of the embryo, and embracing the entire thickness of the mesoderm. It soon becomes crowded ventrally and medianward, so that the lateral layers draw near to the protovertebræ. The lateral band, constituting the intermediate cell-mass of either side of the body, moves toward the median plane, and the two bands finally meet above the intestine, where they form a single compact mass or rod of cells, which in an embryo of nineteen days extends from the pronephros to the posterior end of the trunk. Ziegler ('82, pp. 46, 47) in his description implies, without directly stating it as a

fact, that in the anterior trunk region this cord gradually diminishes, and then disappears.

Wenckebach ('84, p. 235) observed the intermediate cell-mass in Perca fluviatilis. He did not observe its origin, but described it as a solid mass of tissue, situated in the region where afterwards the vena vertebralis is found. This structure is regarded by Wenckebach as the source of the blood corpuscles. The cells composing the axial portion of this cylindrical mass gradually become detached from one another, and are carried away by the plasma which appears at this time; they acquire a yellow tint, and become the blood corpuscles. These conclusions were reached independently of Ziegler's ('82) previous observations on the same structure in the Salmon. In a more recent paper Wenckebach ('86, p. 246) maintains that in Belone acus the intermediate cell-mass arises as a single cord of cells below the chorda, and not as two lateral ones which later unite, as in case of the Salmon, according to Ziegler ('82), and in the Brook Trout, according to Oellacher ('73). As to the method of its origin in Belone acus, the author believes that in an embryo of seventeen days individual cells are set free from the mesoblastic somites, and pass between the chorda and intestinal canal, and in this place undergo proliferation until a massive solid cord of cells is produced, which constitutes the intermediate cell-mass.

In a more recent paper Ziegler ('87) has discussed quite fully the fate of the intermediate cell-mass and its relation to his formative tissue, "Bildungsgewebe." The latter corresponds in general to Hertwig's "Mesenchyme." Ziegler assigns to it a comprehensive meaning. According to his use of the term, Bildungsgewebe embraces a wide range of tissues of various origin, which in distinction from epithelial tissue consist of cells more or less independent of histological connection with one another, or connected only by means of delicate processes; in other words, the term includes all mesodermic primitive connective tissue, including the blood corpuscles. The use of the term enables the author to make a simple general classification of the mesoderm in Vertebrates, viz. (1) the muscle-plates, (2) lateral layers, and (3) formative tissue.

The formative tissue, which arises in later stages, is, according to Ziegler's view, chiefly formed from the lower, hinder margins of the protovertebræ. He is inclined to believe that the intermediate cell-mass also may yet be shown to be in histological connection with the protovertebræ, and hence prefers not to separate intermediate cell-mass and formative tissue. At the same time this observer regards the

intermediate cell-mass as the beginning of a blood-vessel, which is formed as a solid mass, of which the peripheral cells constitute the venous wall, while its central cells float away as blood corpuscles. In later stages of the Salmon, Ziegler has traced the cells of the intermediate cell-mass in their migration to the ventral side of the intestine and over the yolk, where they practically separate the yolk below them from the lateral layers above.

Wiedersheim ('90, p. 131, Taf. VI.) has shown that in later stages of Proteus anguineus, the segmental duct ("Vornierengang") lies in a "blood space" just below the aorta and above the intestine. These blood spaces come from the two sides and are united in the median line, hence their contour in a cross section shows a double or paired outline. They are densely packed with blood corpuscles, and, no doubt, represent the posterior cardinal veins. Some distance (fifteen sections) back of the nephrostome (Taf. VI. Fig. 10) the segmental ducts are distinctly formed, as seen in transverse sections, one on each side of this bilobed mass of cells.

(*b*) *The Origin of the "Intermediate Cell-mass" in Fundulus.* — In Fundulus the intermediate cell-mass originates in two ways; it appears both as a primary and as a secondary formation. It first appears in about the middle of the trunk region, where it occurs as a cord of cells between the protovertebræ and lateral layers, at the time the latter are cut off. In this region it probably retains no histological connection with either protovertebræ or lateral layers. In a more anterior region it is also independent of the protovertebræ from the time of its earliest formation, but here it remains for a time in histological union with the proximal margin of the lateral layers, from which it is subsequently cut off as a secondary process.

This separation of the intermediate cell-mass from the proximal margin of the lateral layers proceeds forward from the anterior limit of its primary formation to the region of the nephrostome. It may be stated that in Fundulus the intermediate cell-mass on either side of the embryo moves ventrally toward the median plane, and that the two structures meet under the chorda; but this statement must be modified to represent the exact conditions in the two regions.

In the region of its primary formation, the intermediate cell-mass does, indeed, pass ventrally as a mass of cells, and take its position under the chorda; but in the region of its secondary formation, although it begins this ventral migration, it never reaches the median line as a compact mass. When it reaches the level of the future seg-

mental duct it remains here for a time as an undifferentiated mass of cells, from the ventral part of which individual cells sever their connection and pass to a position under the chorda. In the region of the nephrostome, where no intermediate cell-mass is formed, individual cells are given off from the proximal margin of the lateral layers, and pass ventrally under the chorda in a manner similar to those contributed by the intermediate cell-mass.

In an embryo of about three days the intermediate cell-mass is distinctly formed from the vicinity of the sixth protovertebra backward, but in this region (Plate II. Fig. 15, *cl-mo.i'm.'*) and through a short distance in front of it (Fig. 14^a, *cl-mo.i'm.'*), although the protovertebræ are distinctly cut off from the remaining portions of the mesoderm, yet the line of separation between intermediate cell-mass and lateral layers is only faintly outlined. A little later, in an embryo of three and a half days, this structure is distinctly differentiated over a region extending from the sixth (Figs. 28, 29) as far forward as the third protovertebra (Fig. 26).

At this stage the ventral migration of mesodermal elements begins in this region. At first only a limited number of cells migrate to the median line under the chorda (Plate IV. Fig. 27^a, *nl.**, *nl.*†), but later they are more numerous (Plate V. Fig. 33, *cl-mo.i'm.'*); yet the total number of cells which reach the median line is never as great as in the posterior part of the trunk.

In the region of the second protovertebra (Plate IV. Fig. 25) the endoderm abuts bluntly against the proximal region of the lateral layers, which has shifted about half-way down along the side of the protovertebra. Here there is no positive evidence of any outgrowth from the lateral layers toward the median line, but frequently nuclei are found which are of doubtful origin (*nl.*††, Fig. 25), arising either from protovertebra or from lateral layers. In the region about opposite the middle of the third protovertebra (Fig. 27) the endoderm has not yet begun the infolding of its distal margin to form the intestine, and hence it extends farther out under the lateral layers than in the region of the second protovertebra (compare *en'drm.*, Figs. 25 and 27), and the lateral mesodermic layers (*so'plu.* and *spl'plu.*, Fig. 27) extend farther under the protovertebra than they do in a more anterior region. In a later stage, the nephrostome is formed in the proximal region of the lateral layers, opposite this protovertebra (Fig. 27). In the same protovertebra, but in its posterior region (Fig. 27^a) nuclei (*nl.*†) which evidently originate from the proximal region of the lateral lay-

ers, pass ventrally under the chorda. Here too, as in case of Figure 25, are nuclei (*nl.††*) the origin of which is doubtful. This condition obtains through the third protovertebra also. In the region from the third to the sixth protovertebra (Fig. 29) the condition of the mesoderm is quite different. Here the proximal part of the lateral layers is cut off, and constitutes the intermediate cell-mass (*cl-mo.i'm.'*, Figs. 28 and 29). From the ventral and inner region of this structure cells are given off, which pass toward the median line.

The intermediate cell-mass moves still farther medianward under the protovertebra, and the cells from the two sides accumulate in the median line under the chorda. Back of about the sixth or seventh protovertebra, the elements which have thus been aggregated under the chorda form a mass of considerable volume (*cl-mo.i'm.'*, Plate V. Figs. 36 and 37). In later stages this mass extends forward, but in a much reduced volume, into the region of the nephrostome, or third protovertebra (Fig. 33).

The mesodermal elements which may be said to migrate toward the subnotochordal region are the following: —

(1) The original intermediate cell-mass in the region of its primary formation.

(2) Individual cells from the intermediary cell-mass in the region of its secondary formation.

(3) Individual cells from the lateral layers in the region of the nephrostome, and forward to the head-mesoderm.

(4) Individual cells from the ventral region of the protovertebræ, at an early stage.

(5) The formative tissue (Ziegler's Bildungsgewebe) from the lower margins of the protovertebræ at a much later stage.

(*c*) *Concerning the Fate of the "Intermediate Cell-mass."* — I have not made a detailed study of the fate of this structure in Fundulus, and my only reason for including a brief account of my observations on it is based upon the fact that some recent observers have held that it is intimately related to the beginning (Anlage) of the pectoral fins; in fact, that it constitutes one of the sources of the mesodermal elements which are contributed to the latter structure. It seems to me that in Fundulus such a relation between intermediate cell-mass and pectoral fin is impossible; the basis for this belief I shall point out later.

It is very evident, however, that the lateral region of the intermediate cell-mass gives rise to the segmental duct. The anterior region of the segmental duct is formed at nearly the same time as its nephrostome.

In Figures 26 and 27 (Plate IV.) is represented the region of the nephrostome just prior to the beginning of its formation, and Figures 28 and 29 represent the anterior region of the segmental duct in the same embryo. At this stage no trace of either structure can be seen, but a little later both appear. In an embryo about six hours older than the stage to which reference has just been made, these structures are in process of formation. In the corresponding protovertebræ (Plate V. Figs. 31, 32, 33) the nephrostome (*pr'nph.*) is in process of formation as an evagination of the proximal region of the lateral mesodermic layers opposite the third protovertebra. The lumen of the nephrostome, continuous with the body cavity (*cœl.*), is plainly seen and persists very conspicuously in stages more advanced (Plate VI. Fig. 42, and Plate VII. Fig. 46). In the fourth protovertebra of the embryo in which the nephrostome is forming, a mass of cells is seen in a position corresponding to the nephrostome, but it is without any distinct connection with the proximal margins of the lateral layers. This mass of cells is also more or less detached from the principal part of the intermediate cell-mass, which now occupies a position under the chorda. In the next (fifth) protovertebra (Fig. 34) this structure is plainly recognized as the segmental duct (*dt. seg.*); it is independent of any connection with the lateral layers, and more nearly detached from the intermediate cell-mass than in the fourth protovertebra; its cells are arranged in a peripheral order, and a faint lumen can be observed. The condition of the segmental duct for some distance back of the fifth protovertebra is the same as here, unless perhaps the development may be slightly more advanced than in the extreme anterior end. It appears, therefore, that the anterior portion of the segmental duct is developed from the distal (lateral) margin of the intermediate cell-mass; that, as the nuclei arrange themselves to form the walls of the tube (Fig. 28), a lumen is formed and the whole is gradually cut off from the inner (axial) portion of the intermediate cell-mass, which passes to the axis of the embryo, becomes more voluminous, and, as we shall see, has a different fate. In more advanced stages the duct becomes more perfectly cylindrical, and its central area more nearly circular in cross sections. (Compare *dt. seg.* in Figs. 35, 43, 44, 49, 50.)

The segmental duct retains its original position, but the proximal margin of the lateral layers passes toward the median line, and, as the entoderm closes in to form the tubular intestine, these layers press upon it from the two sides, and later clasp it, as may be seen by reference to Figures 34, 35, and 43. Hence it follows from these changes that the

segmental duct, subsequent to its early development, occupies a position along the dorsal surface of the somatopleure (*so'plu.*, Figs. 35 and 43), with which it lies in close juxtaposition.

It should be noted in this connection that in the posterior trunk region the segmental duct is developed somewhat later than in the more anterior region, and its development is also slightly modified, owing to the great volume of the axial portion of the intermediate cell-mass (Fig. 37) and the retarded progress in the development of the lateral layers and intestine; but its source is exactly the same as in other regions, viz. from the lateral portion of the intermediate cell-mass.

The fate of the axial portion of the intermediate cell-mass is not so easily traced as that of the lateral portion. I have not been able to demonstrate any differentiation of it prior to the beginning of the third day, and therefore only after the formation of the nephrostome and segmental duct in the anterior trunk region. That it is the source of the blood corpuscles seems to me almost beyond doubt, and that it also contributes the elements which form the walls of the aorta, at least in the middle and posterior trunk regions, seems to me equally certain; but what *rôle* it takes in the anterior trunk region, where it consists of relatively few cells which are brought in juxtaposition with elements from other sources, is not easily determined; it is, however, highly probable that these elements have the same fate as those originating from the same structure in a more posterior region of the embryo, — that it gives rise to the blood corpuscles.

It is worthy of note, that before the cells coming from the intermediate cell-mass have reached their position under the chorda, a few nuclei, whose origin I have referred to the ventral margins of the protovertebræ, are seen in this position. These are the nuclei (*nl.**, Figs. 24–27^a) of cells which lie directly below the chorda and form a slender structure resembling the subnotochordal rod in those Chordata which are lower than the Teleosts; but the origin of the subnotochordal rod is in all cases, so far as I know, referred to the endoderm. Hence, if my supposition concerning the origin of these cells is correct, the two structures cannot be homologous, one being mesodermal and the other endodermal in origin. There is, however, this similarity, that this structure in Fundulus, as in case of the subnotochordal rod, does not exist until some time after the formation of the chorda, and that it entirely disappears at a later stage. In an embryo of three days (Plate II. Figs. 11–14) no trace of these nuclei can be seen between the chorda and the layer of entoderm below it; about two days later, when the intestine

in the anterior region of the trunk has just closed, it has again entirely disappeared. The identity of these nuclei is lost at the time of the formation of the dorsal aorta, but the subnotochordal rod, according to Balfour's ('81, pp. 620–622) account, persists until later, and then atrophies.

Whatever may be the source and fate of these cells in Fundulus, it is certain that there are other cells contributed from the ventral margins of the protovertebræ which do not take this definite arrangement, and whose fate is not involved in much doubt. These nuclei (*nl.*, Fig. 30, and *nl.**, Figs. 24, 25) I believe to be concerned in the formation of the walls of the aorta. In later stages, subsequent to the formation of the aorta (Figs. 42–44), there is also a very large contribution of elements from the ventral region of the protovertebræ to the median line. The greater part of the axial intermediate cell-mass is probably converted into blood corpuscles, which are seen enclosed within the delicate wall of the aorta (Figs. 35 and 43) from its earliest formation.

By a comparison of Figures 34 and 35 (Plate V.) from the fifth somite, the change which takes place in the axial cell-mass may be appreciated. These drawings represent sections from the corresponding regions of embryos of four and five days respectively. In Figure 34, no differentiation of the intermediate cell-mass (*cl-mo. i'm.'*) is to be seen, but it consists of closely packed indifferent cells. In Figure 35, the aorta is formed, its walls being outlined by delicately drawn-out cells, in section spindle-shaped, enclosing blood corpuscles (*cp. san.*), which must have originated from the cell-mass. Outside the walls of the aorta, and between it and the intestinal canal, are seven nuclei, which are the remaining representatives of the original cell-mass. The change has resulted in the densely packed cell-mass being replaced by the aorta, its contained blood corpuscles, and the small number of nuclei on its ventral side where the trunk vein will be formed later. The aorta can be traced from the anterior trunk region to about the seventh somite.

The number of nuclei, or blood corpuscles, lying within the aorta, increases in passing back from the region of the nephrostome, until a point is reached where it is relatively large, and the mass of cells within it seems to be continuous with the original cell-mass, and aortic walls cannot be readily distinguished.

The following table shows the variation in the number of nuclei lying inside and those lying outside the aorta, through a series of consecutive sections, beginning with the fifth somite of an embryo of about five days.

No. of Section.	No. of Nuclei within the Walls of the Aorta.	No. of Nuclei outside the Walls of the Aorta.
1	7	0
2	6	0
3	7	0
4	7	2
5	4 (?)	4 (?)
6	4	7
7	3	7
8	7	5
9	7	8
10	6	8
11	6	7
12	8	10
13	10	7
4	11	8

(*d*) *Comparative Review.* — From a brief summary and comparison of the observations on the origin and morphology of the intermediate cell-mass in Teleosts, it appears that Wenckebach's ('86, p. 246) account for Belone differs materially from Oellacher's ('73) for the Brook Trout, as well as from Ziegler's ('82) observations upon the Salmon and my own on Fundulus; that is, he did not observe its true lateral origin, or any modification of it in different regions of the trunk. If Wenckebach's account of the origin of this structure is correct and complete, Belone is an exception among Bony Fishes, and differs materially, in this point, from other groups of Vertebrates. As has been stated (p. 113), Wenckebach refers the origin of the intermediate cell-mass to individual cells, which migrate from the protovertebræ to a position under the chorda, and here proliferate and form the compact cord of cells which may be designated the axial portion of the intermediate cell-mass. My observations on Fundulus agree in general with Oellacher's for the Brook Trout, so far as he describes the structure. I have seen no evidence in Fundulus in support of the theory toward which Ziegler inclines, namely, that the intermediate cell-mass retains histological connection with the protovertebræ.

Ziegler's observations on his "formative tissue" in the Salmon, and his study of the relation between it and the intermediate cell-mass, are based on relatively older stages than those in which I have observed the origin of the intermediate cell-mass in Fundulus. The identity of the intermediate cell-mass and the formative tissue arising from the protovertebræ, or even an intimate relation between the two in Fundulus, must be questioned when we consider the fact that the intermediate cell-mass

originates prior to the formative tissue, and in a very different manner; that it has already given rise to the segmental duct, and that the dorsal blood-vessel and contained blood corpuscles have taken their origin from it before the period is reached at which the formative tissue arises from the protovertebra. According to Ziegler's account, the protovertebræ, at the stage in which the formative tissue arises, already show differentiation of muscle fibre. In Fundulus these two processes also occur during the same period (*fbr. mu.*, Plate VI. Figs. 43, 44), but subsequent to the formation of the intermediate cell-mass. It is true, however, that a certain portion of this cell-mass still remains in an indifferent state at this stage, and its loosely disposed cells are brought into juxtaposition with those of the formative tissue, and are identical with them in appearance.

If Ziegler's comprehensive definition for Bildungsgewebe be employed, all migatory cells which originate from the mesoderm, of whatever source, must be included in it; hence those originating from the intermediate cell-mass, and indeed the entire cell-mass itself (excepting perhaps its lateral portion, which gives rise to the segmental duct, whose cells in the anterior trunk region have from the beginning more or less of an epithelial character) are also embraced under this term; i. e. the intermediate cell-mass is Bildungsgewebe. Ziegler says ('87, pp. 646, 651) that *the intermediate cell-mass can at no time be distinctly separated from Bildungsgewebe.* This statement is superfluous, unless it is intended to mean that the formative tissue (migratory cells) which arises from the intermediate cell-mass is identical with that arising from other sources (the lower margin of the myotomes); but with this construction, the statement is true only so far as the appearance of the cells and their migratory condition are concerned, the *source* and *fate* are different.

I believe that the origin of the "blood-spaces" in Proteus (Wiedersheim, '90) has not been traced through earlier stages; but it seems to me very probable that they represent the intermediate cell-mass of Teleosts, and that the bi-lobed condition of the cell-mass in the Salmon is here a more permanent one, and that the segmental ducts, instead of being formed in the lateral region of the intermediate cell-mass, as in the case of Fundulus, are here developed in a less peripheral region. It appears that the segmental ducts, which at an earlier stage lie in a central region of the "blood-spaces," later come to occupy a position entirely outside of them, but near their lateral boundary, as in the case of the segmental ducts in Teleosts. In Proteus the bi-lobed cell-mass, or the "blood-

spaces," are said to move from their original lateral position and unite in the median line between the chorda and intestinal canal, which is also true of the intermediate cell-mass.

When the source and fate of the intermediate cell-mass in Teleosts are compared with those of the corresponding structure in other Vertebrates, — the "intermediate cell-mass" in Elasmobranchs, Lacerta, and Birds, — it seems to me that the negation of the homology of these structures (Ziegler) is not justifiable; but that, on the other hand, a comparative view affords evidence in favor of such homology. The variation in the morphology of the intermediate cell-mass in Teleosts, Elasmobranchs, Lacertilia, and Birds seems comparatively insignificant when we consider its variation in representatives of the same group, e. g. the Chick and Duck, and especially when its variation in the different regions in the same embryo is considered. When we take into account the characteristic peculiarity of the Teleostean embryo, — namely, the compact condition of the primitive layers, the embryo being pressed down into the relatively large amount of yolk beneath, — a cause is found which is apparently adequate to explain this modification in the morphology of structures which are homologous. The points of similarity in the origin and fate of these structures in the different groups of Vertebrates are strong and significant.

VI. Origin of the Pectoral Fin.

(*a*) *Proliferation of Somatopleure.* — The earliest trace of any modification of the mesoderm in the region of the pectoral fin takes place opposite the nephrostome (Plate V. Fig. 33, *so'plu.*), and consists of a thickening of the somatopleuric layer. This is observed in an embryo of eighty-four hours. In front of this region, opposite the third protovertebra, the somatopleure consists of a single layer of cells (*so'plu.*, Fig. 30), and as such is continuous with the head-mesoderm. At an earlier stage, in the region of the first and second protovertebræ there is a thickening of the somatopleure (Plate IV. Fig. 25, *so'plu.*), which extends forward to the head-mesoderm; but this is only a temporary condition, which exists at the time when the lateral margin of the entoderm (*en'drm.*, Fig. 25) begins to fold toward the axis to form the intestine (*in.*, Fig. 30). During this period there is apparently a crowding of cells toward the proximal region of the somatopleure, which later, when the entoderm is well advanced in the process of its infolding, assumes again the form of a single layer of cells (*so'plu.*, Fig. 30).

The cell proliferation in the somatopleure seems therefore to produce a temporary thickening in front of the third protovertebra, but the only region in which this original thickening remains permanent is that of the nephrostome. I am therefore led to believe that the condition in the second and third protovertebræ is not concerned with the beginning of the pectoral fin, and that, if there is at this stage any trace of its formation, it must be referred to the region opposite the nephrostome.

Shortly after the nephrostome is formed, a thickening of the somatopleure by cell proliferation takes place, which is permanent, and leads to the development of the pectoral plate. This modification of the somatopleure extends from the head-mesoderm backward through the region opposite the third protovertebra. It may be said that it develops from the head-mesoderm in a posterior direction ; yet from the first the most conspicuous portion of this thickening is not in the anterior part of the pectoral region, but rather in the middle of it, first in the region of the third, and later opposite the second protovertebra.

It is clear that at the time of the beginning of this thickening of the somatopleure, and during a brief period following, there is no connection between it and the adjacent protovertebræ (see Plate V. Figs. 30–34). In a later stage, however, such a connection is established.

I shall now describe a stage in which the pectoral plate is well advanced, and is in histological connection with the adjacent protovertebræ.

(*b*) *Contribution of Myotomic Elements to Pectoral Plates.* — In front of the first protovertebra the indifferent head-mesoderm extends laterally, and diminishes to a single layer of cells (Plate VI. Fig. 39) corresponding to the somatopleure in the protovertebral region. This lateral somatopleuric plate thickens in the region opposite the first protovertebra ; the thickening may be regarded as the anterior region of the pectoral plate, and results principally from a cell proliferation in the somatopleure. In the region of the first protovertebra there is no separation between the protovertebræ and the lateral or pectoral plates, i. e. the protovertebra passes gradually over into the lateral layer, which is in no sense cut off from it. This lateral mesodermic plate (*la. pct.*, Fig. 40) is therefore continuous anteriorly with the head-mesoderm, and axially with the first protovertebra ; in its relation to the cœlomic cavity it represents morphologically the somatopleure. The somatopleuric thickening is still more pronounced in the region of the second protovertebra (Fig. 41, *la. pct.*), where it is about three or four cells in thickness. The pectoral plate is here so closely connected with the protovertebral mesoderm as to render it impossible to distinguish any sharply defined boundary between them.

In the region of the third protovertebra it (*la. pct.*, Fig. 42) is only about two cells in thickness, and is less intimately connected with the protovertebra, while in the region of the fourth protovertebra the pectoral plate or somatopleuric thickening (Fig. 43, *so'plu.*) is independent of the protovertebra, and is composed of but a single layer of cells. The nuclei are however closely crowded in the somatopleure, and give evidence of active karyokinetic change. Caudad of the fifth protovertebra, the somatopleure consists of a thin single layer of cells, independent of the protovertebræ.

It has been pointed out in the foregoing account, and demonstrated in the figures of Plate VI., that a connection between the pectoral plate and adjacent protovertebræ has been established. The method by which this connection has been effected and its morphological significance remain to be considered. It is evident that the pectoral plate is passive in this process, whereas elements from the protovertebræ lose their former epithelial arrangement in its peripheral layer and pass over into the pectoral plate. It can hardly be said that the elements in this contribution take the form of well defined cell-masses or buds, nor are they strictly isolated individual cells, and yet to a certain extent both conditions exist. The first step in establishing this connection consists in an increase in the number of cells at the outer ventral margin of the protovertebra, at this stage more correctly designated myotome. The peripheral or somatic layer of cells in the myotome, the cutis-plate, is only one cell deep (Plate VII. Fig. 47, *la. mu.*), excepting in the region where later the connection is formed with the pectoral plate. Here by cell proliferation the peripheral layer (cutis-plate) is augmented to a mass of cells (*pr'f. my'tm.*, Fig. 47) which projects laterally in the direction of the pectoral plate, finally, in fact, extending over the proximal margin of the latter. This projection is especially pronounced in the middle of the first, second, and third myotomes. In the next step, the cells of those myotomic proliferations, which already lie in contact with the pectoral plate, fuse with the latter; that is, the ventral margin becomes continuous with the pectoral plate, as already described, so that the mass of cells constituting the former projection of the myotome is gradually reduced until there is a complete blending of myotome (Plate VIII. Fig. 51) and pectoral plate. Subsequent to this connection of myotome and pectoral plate, cell proliferation is continued in the region of the former myotomic projection, and the elements thus produced seem gradually to crowd outward into the pectoral plate.

The myotomic projections here described are observed in the three anterior myotomes; but in the posterior region of the pectoral plate, i. e. the region of the fourth myotome, no such distinct cell-mass is produced prior to the connection of myotome and pectoral plate. The process in this region seems to consist from the first in the passing over of *individual* cells into the pectoral plate (*pr'f. my'tm.*, Figs. 48, 49, and 50).

It is highly probable that the projection of the ventral portion of the myotome is due in part to the tendency of the myotomes at this stage to fold upon themselves. This tendency can be readily seen in sections back of the pectoral region (Fig. 44), and is the result of the relatively large amount of yolk in the Teleostean ovum, causing not only the lateral layers, but also the lower portion of the myotomes, to present the appearance of being pressed upward and outward. While it is true that myotomes back of the pectoral region, as well as those adjacent to the pectoral plate, show this tendency of their ventral portions to project outward, two points of difference must be noted. (1) In the pectoral region the myotome extends outward relatively much farther than in the post-pectoral region (compare Figs. 44 and 47); and (2) the peripheral layer of this projecting portion of the myotomes in the post-pectoral region consists of a layer only one cell in thickness, similar to that of the upper and outer boundary of the myotome, whereas the laterally projecting portion of the myotome in the pectoral region, prior to its connection with the pectoral plate, consists of a mass of indifferent cells, equivalent to a layer three or four cells in thickness (compare Figs. 44 and 47). This condition of the myotome and the accumulation of this mass of indifferent cells cannot, therefore, be regarded as insignificant, or common to all regions of the trunk, but must be looked upon as a growth leading to the contribution of elements to the pectoral plate. I am at present undecided whether any distinction should be made between the earlier contribution of elements, which is in the form of a mass of cells, and the later, which consists of single cells. It seems to me, however, to be beyond doubt that in both cases the source of the elements is the peripheral layer of the myotome, the cutis-plate, and I am inclined to believe, both from this and from the fact that in the posterior pectoral region the contribution seems to be from the beginning by single cells only, that the latter form may be regarded as a modification of the earlier and more conspicuous method.

In addition to this contribution from the muscle plates, it is highly

probable that single cells, originating in the ventral and more axial region of the myotome, pass over into the pectoral plate. There are cells in this region such as Ziegler ('87) describes and designates "Bildungsgewebe," which exhibit active nuclear change, but I have not seen sufficient evidence in Fundulus to affirm their migration into the pectoral plates. If a migration of such elements does take place, it must be subsequent to the connection between the myotomes and pectoral plate, i. e. subsequent to the contribution by the cutis-plate, since prior to this there is no connection between the elements in question and the pectoral plate.

The inferences which I am led to draw from my observations on Fundulus concerning the origin of the pectoral fin are: (1) that the first step is a differentiation in the somatopleure caused by cell proliferation in the region of the nephrostome; (2) that this process leads to the formation of the pectoral plate; (3) that a connection is formed between each of the four most anterior myotomes and the pectoral plate, and that elements from the peripheral layer of these myotomes are contributed to the pectoral plate; (4) that, although the lateral portion of the head-mesoderm is continuous with the lateral plates, as its axial region is with the most anterior protovertebra, the head-mesoderm does not really appear to be concerned in the earliest formation of the pectoral fin.

VII. Concerning the Relation of the Pectoral Plate and the Ectodermal Fold.

The earliest trace of a modification in the ectoderm which can be regarded as leading toward the formation of an ectodermal fold in the region of the pectoral fin, is observed in an embryo of about four days, and this modification (Plate VII. Fig. 46) merely consists of a more compact arrangement of the nuclei in the lower cell layer of the ectoderm (*la. sns. ec.*, Fig. 47) than is found in the preceding stages. This modification, however, does not in any sense involve the superficial ectodermal layer (*cta.*, Fig. 47); it is not of the nature of an evagination or folding of the layers of the ectoderm, and it does not at this stage modify even the external contour of the sections. But at this stage the mesodermal pectoral plate is already far advanced.

An ectodermal fold cannot be seen before the fifth day; the ectoderm then rises into a distinct fold (Plate VIII. Fig. 54, *pli. ec'd'n.*) and extends in a longitudinal direction, but not quite parallel, to the axis of

the embryo. Concerning the nature of this fold in Fundulus, I may say that my observations confirm, in the main, 'Swirski's ('80) description for the Pike. The ectodermal fold develops independently of the mesoderm; the nuclei of the lower layer of the ectoderm are relatively large, and, like their cells, are more or less wedge-shaped in outline. It is worthy of note in this connection that the cuticular layer of the ectoderm is also peculiarly modified in the region of the ectodermal fold. The nuclei lose their characteristic flattened appearance (Fig. 54, *nl.*[1]), and become irregular in form and much enlarged. So great is their increase in size, that, although the cuticular layer is already materially thickened, still in the region of each nucleus the surface is carried outward by the enlarged nucleus beneath, and the external contour is thus thrown into numerous irregular elevations (Fig. 54). In Fundulus, as in the Pike, the ectodermal fold does not extend back along the side to the ventrals, but only through the region of the pectoral plates. It cannot be held that the ectodermal fold takes its beginning as the result of an outward growth of the mesodermal cells, for the latter do not commence their outward migration until after the formation of a distinct lumen or fold (*pli. ec'drm.*, Fig. 55). The statement that the formation of the ectodermal fold takes place prior to the outward migration of the mesodermal elements cannot be construed to mean that the modification of the ectoderm precedes that of the mesoderm in the development of the pectoral fin; since it has been shown in Fundulus (Plate VI. Figs. 40–43) that the pectoral plate is developed before any modification in the ectoderm.

Hence it follows that in Fundulus the ectodermal fold does not begin to be formed until several days after the formation of the pectoral plate in the mesoderm, as already described; and the statement of authors that the earliest trace in the development of the pectoral fin in Osseous Fishes is the formation of the ectodermal fold, does not apply to Fundulus at least.

Nor can it be said that there is at any time in Fundulus any trace of a continuous longitudinal modification of the ectoderm along the side of the embryo, such as has been observed by Balfour in Elasmobranchs, and maintained by Ryder for the Cod, Stickleback, Shad, etc. I am convinced from my own observations upon Shark embryos, that in the latter, as in Fundulus, the earliest step in the development of the pectoral fin is not a modification of the ectoderm, as supposed by Balfour and accepted by Dohrn, but that the beginning must be referred to the proliferation of the mesoderm in the somatopleure, as I have

already pointed out for Fundulus (p. 126). My observations on the Shad (*Clupea sapidissima*) and the Cod (*Gadus morrhua*) also confirm this point for other Osseous Fishes besides Fundulus, and I believe that this condition is typical, if not constant, in the entire group of Fishes.

As I have already stated (p. 96), Oellacher traced the origin of the pectoral fin from the mesoderm. He did not, however, believe simply in the priority of the mesodermal modification, for he supposed an ectodermal fold to be absent in the case of the pectoral fin in the Trout. He evidently saw the pectoral plate at a stage prior to the ectodermal modification,—a stage presumably corresponding to Figure 41 (Plate VI.) of Fundulus,—but he did not discover that *subsequently* an ectodermal fold is developed; hence his observation did not reveal the error of Balfour and others, who assumed that the ectodermal fold is the first step in the development of the pectoral fin.

I am unable to make any comparison between the condition of the unpaired fins in Fierasfer and my own observations in Fundulus, as I have discovered no structure in the pectoral fin of Fundulus comparable to the homogeneous stratum which has been observed by Emery, and is regarded by him as partly mesodermal and partly ectodermal in origin.

The extreme view held by Prince ('86, p. 697), that the pectoral fins of Osseous Fishes are of ectodermal origin, and are differentiations of a continuous lateral expansion of the epiblast, seems to me to be based more upon theoretical considerations than upon observed facts. The only way in which I can account for the author's description is to assume that his "two epiblastic lamellæ (separated by a fissure) lying flat upon the vitellus," which he regards as the beginning of the pectoral fin, are really the primitive embryonic layers, either including the three at an early stage (compare Fig. 5 in Fundulus) before their complete differentiation, or including only ectoderm and mesoderm at a later stage (compare Fig. 26 in Fundulus). Indeed, more recently a similar belief is defended by M'Intosh and Prince ('90, pp. 800–803) in their joint paper on the development of Teleosts. In this paper the ground taken is still more peculiar, and the interpretation is much involved in speculation.

I have already quoted at some length the views of these authors (pp. 98, 99), and need here only recall the fact that they regard the lateral margin of the blastoderm at an early stage, virtually before the complete differentiation of the primitive layers, as the beginning of

the pectoral fins. Their assumption that the pectoral fin begins its differentiation in a stage as early, for example, as that shown in Figure 5 (Plate I.) for Fundulus, meets with serious obstacles. It presumes a recognition of the pectoral fin prior to the complete differentiation of the primitive germinal layers themselves, and hence refers the beginning of the pectoral fin to a structure (an "alar expansion" which "consists of epiblast and hypoblast") which evolves the entoderm or hypoblast. But in what sense the entoderm is identified with the beginning of the pectoral fin they have not explained.

It is evident that a view of the blastoderm seen from above (Plate I. Fig. 1) presents such lateral expansions of the primitive layers as M'Intosh and Prince have designated alæ. These expansions not only extend along the sides of the embryonic axis, but are also continuous in front of the embryonic swelling; to draw any analogy, however, between this blastodermic rim and the pectoral fin, or to regard this condition of the primitive layers as representing in any sense the pectoral or paired fins, seems to me fanciful and unwarranted. At a later stage (Plate I. Fig. 3), in which the somatopleure has undergone a thickening in the pectoral region, or still later, when the pectoral plate is formed, it is true, as described by these authors, that a parietal (lateral) thickening in the pectoral region may be observed when the embryo is examined from above in surface view or by transmitted light; but this appearance is at first due entirely to a modification of the somatopleure, and at no time are the other layers — splanchnopleure and entoderm — concerned. This fact can be readily demonstrated by serial sections from the proper stages of the embryo; hence I believe that the interpretations of these authors upon the origin of the pectoral fins are misleading, and that their views are untenable.

Ziegler maintains that the thickening of the somatopleure is accompanied by the upheaval of the ectoderm, and evidently does not regard the ectodermal fold as the first step in the development of the pectoral fin in the embryo of Elasmobranchs. In his studies of the Salmon and Pike he reaches substantially the same conclusion, but gives no further details concerning the formation of the lateral longitudinal fold of ectoderm. The facts upon which his statements are based may be identical with the conditions in Fundulus, but, not being specially interested in the ectoderm, he may have omitted a more exact account of its modification; at any rate, it cannot be affirmed that in Fundulus the proliferation or thickening of the somatopleure is at first accompanied by an upheaval or any other modification of the ectoderm,

this latter change being a secondary step, which is preceded by the proliferation of the somatopleure and the formation of the pectoral plate, as already described. This difference should be noted, that in the Salmon, according to Ziegler's ('87, p. 619) account, the lateral ectodermal fold extends from the pectoral region to that of the anus, whereas in the case of Fundulus no such fold of the ectoderm is found.

I have examined both the Cod and the Shad, in which Ryder affirms that the ectodermal fold is the earliest trace of the pectoral fin, and find that these forms agree with Fundulus to the extent at least that the proliferation of the somatopleure in the pectoral region precedes any specialization or modification in the ectoderm. I cannot account for this difference in our results, unless my supposition, that Ryder's studies were made chiefly without the aid of sections, is correct.

CHICAGO, January, 1892.

BIBLIOGRAPHY.

Balfour, F. M.

'78. A Monograph on the Development of Elasmobranch Fishes. London, Macmillan & Co.

'81. A Treatise on Comparative Embryology, Vol. II. London.

Beard, J.

'89. On the Early Development of Lepidosteus osseus. Preliminary Notice. Proceed. Roy. Soc. London, Vol. XLVI. p. 108.

Bemmelen, J. F. von.

'89. Ueber die Herkunft der Extremitäten- und Zungenmuskulatur bei Eidechsen. Anat. Anzeiger, p. 240.

Braun, M.

'77. Das Urogenitalsystem der einheimischen Reptilien, entwicklungsgeschichtlich und anatomisch bearbeitet. Arb. zool-zoot. Institt. Würzburg, Bd. IV. p. 113.

Conn, H. W.

(See Kingsley and H. W. Conn.)

Dohrn, A.

'84. Studien zur Urgeschichte des Wirbelthierkörpers. VI. Die paarigen und unpaarigen Flossen der Selachier. Mitth. Zool. Stat. Neapel., Bd. V. p. 161.

Eigenmann, Carl H.

'90. On the Egg Membranes and Micropyle of some Osseous Fishes. Bull. Mus. Comp. Zoöl., Vol XIX. p. 133.

Emery, C.

'83. Sulla esistenza del considetto tessuto di secrezione nei Vertebrati. Atti Acc. Sci. di Torino, Vol. XVIII.

Kingsley, J. S., and H. W. Conn.

'83. Some Observations on the Embryology of the Teleosts. Mem. Boston Soc. Nat. Hist., Vol. III. p. 183.

Kölliker, A. von.

'79. Entwickelungsgeschichte des Menschen und der höheren Thiere. 2te Aufl. Leipzig, Engelmann.

M'Intosh, W. C., and E. E. Prince.

'90. On the Development and Life Histories of the Teleostean Food- and other Fishes. Trans. Roy. Soc. Edinburgh, Vol. XXXV., Part III. p. 665.

Mayer, Paul.
'86. Die unpaaren Flossen der Selachier. Mitth. Zool. Stat. Neapel., Bd. VI. p. 217.

Oellacher, J.
'73. Beiträge zur Entwickelungsgeschichte der Knochenfische nach Beobachtungen am Bachforelleneie. V. Zeitschr. f. wiss. Zool., Bd. XXIII. p. 66.
'79. Beiträge zur Entwickelungsgeschichte der Bachforelle. Vorläufige Mittheilung. Bericht. naturw.-med. Verein Innsbruck, p. 141.

Prince, E. E.
'86. Points on the Development of the Pectoral Fin and Girdle in Teleosteans. Rept. Brit. Assoc., 1886, p. 697.

Rathke, H.
'33. Abhandlungen zur Bildungs- und Entwickelungsgeschichte des Menschen und der Thiere. Erste Abhandlung: Bildungs- und Entwickelungsgeschichte des Blennius viviparus oder des Schleimfischen. Leipzig.

Remak, R.
'50–'55. Untersuchungen über die Entwickelung der Wirbelthiere. Berlin, Reimer.

Ryder, J A.
'82. Development of the Silver Gar (Belone longirostris), etc. Bull. U. S. Fish Com., Vol. I. p. 283.
'84. A Contribution to the Embryography of Osseous Fishes, with special Reference to the Development of the Cod (Gadus morrhua). Ann. Report U. S. Com. Fish and Fisheries for 1882, p. 455.
'85. On the Development of Viviparous Osseous Fishes, and of the Atlantic Salmon. Proceed. U. S. Nat. Mus., Vol. VIII. p. 128.
'86. On the Origin of Heterocercy and the Evolution of the Fins and Fin-rays of Fishes. Ann. Report U. S. Com. Fish and Fisheries for 1884, p. 982.
'86a. On the Development of Osseous Fishes, including Marine and Fresh-water Forms. Ann. Report U. S. Com. Fish and Fisheries for 1885, p. 484.

Sedgwick, A.
'80. Development of the Kidney in its Relation to the Wolffian Body in the Chick. Quart. Jour. Micr. Sci., Vol. XX. p. 146.

Swirski, G.
'80. Untersuch. über d. Entwickelung d. Schultergürtels und d. Skelets d. Brustflosse d. Hecht. Inaug. Diss. Dorpat, 1880.

Waldeyer, W.
'69. Ueber die Keimblätter und den Primitivstreifen bei der Entwickelung des Hühnerembryo. Zeitschr. f. rationelle Medicin.

Weldon, W. F. R.

'83. Note on the Early Development of Lacerta muralis. Quart. Jour. Micr. Sci., Vol. XXIII. p. 134.

Wenckebach, K. F.

'84. The Development of Blood-Corpuscles in the Embryo of Perca fluviatilis. Jour. Anat. and Phys., Vol. XIX. p. 231.

'86. Beiträge zur Entwicklungsgeschichte der Knochenfische. Arch. f. mikr. Anat., Bd. XXVIII. p. 225.

Wiedersheim, R.

'90. Beiträge zur Entwickelungsgeschichte von Proteus anguineus. Arch. f. mikr. Anat., Bd. XXXV. p. 121.

Ziegler, H. E.

'82. Die Embryonale Entwickelung von Salmo salar. Inaug. Diss. Freiburg, 64 pp.

'87. Die Entstehung des Blutes bei Knochenfischembryonen. Arch. f. mikr. Anat., Bd. XXX. p. 596.

'88. Der Ursprung der mesenchymatischen Gewebe bei den Selachiern. Arch. f. mikr. Anat., Bd. XXXII. p. 378.

EXPLANATION OF FIGURES.

All the figures were drawn with the aid of an Abbé camera lucida from preparations of Fundulus heteroclitus, Linn. All transverse sections were taken in serial order from the anterior toward the posterior end of the animal, and the drawings represent the anterior faces of the sections. The drawings of frontal sections represent the dorsal faces.

ABBREVIATIONS.

ao.	aorta.
au.	auditory vesicle.
bl'po.	blastopore.
brs. brn.	gill-pouch.
can. med.	medullary canal.
cav. pi'cr.	pericardial cavity.
cd.	chorda.
cd. sp.	spinal cord.
cl. cn't. tis.	connective-tissue cell.
cl.-mo. i'm.'	intermediate cell-mass.
cl. mu.	muscle cell.
cl. pig.	pigment cell.
cn't. tis.	connective tissue.
cœl.	body cavity.
cp. san.	blood corpuscles.
cta.	cuticular layer of ectoderm.
dt. sg.	segmental duct.
ec'drm.	ectoderm.
ec'drm.'	ectodermic thickening.
en'c.	brain.
en'drm.	endoderm.
fbr. mu.	muscle fibre.
fos. olf.	nasal pit.
fs. brn.	gill-cleft.
in.	intestine.
la. l.	lateral plate.
la. mu.	muscle plate.
la. pct.	pectoral plate.
la. sns. ec.	lateral sensory layer of ectoderm.
ms'drm.	mesoderm.
ms'drm. ax.	axial mesoderm.
ms'drm. cap.	head-mesoderm.
my'tm.	myotome.
nl.	nucleus.
nl.'	nucleus in process of division.
nl.''	nucleus soon after division.
*nl.**	nucleus from protovertebra (?).
nl.†	nucleus from lateral plate.
nl.††	nucleus of doubtful origin.
nl.[1]	spindle-shaped nucleus of the cuticular layer.
nl. pi. 'bl.	periblast nucleus.
oc.	eye.
o. ln. l.	lateral line organ.
pin. pct.	pectoral fin.
pli. ec'drm.	ectodermic fold.
pli. l.	lateral fold.
pli. pct.	pectoral fold.
pr'f. my'tm.	proliferation from myotome.
pr'nph.	pronephros (head-kidney).
pr'vr.	protovertebra.
scl'tm.	sclerotome.
so'plu.	somatopleure (somatic portion of mesoderm).
spl'plu.	splanchnopleure (splanchnic portion of mesoderm.
tb. sg.	segmental tube (duct).
va. san.	blood-vessel.
vn. marg.	marginal vein.
vs. au.	auditory vesicle.
vs. au.'	ectoderm from which *vs. au.* is formed.
vs. K.	Kupffer's vesicle.
vs. opt.	optic vesicle.

PLATE I.

Fig. 1. Clove-oil preparation of a blastoderm, shortly before the closure of the blastopore, 46 hours after fertilization of the ovum. Perenyi's fluid. Czokor's alum cochineal. × 48.

Fig. 2. Clove-oil preparation of an embryo of 52 hours, soon after the closure of the blastopore. The optic vesicles are prominent, but the auditory vesicles have not yet been formed. Perenyi's fluid. Czokor's alum cochineal. × 48.

Fig. 3. Clove-oil preparation of an embryo of 90 hours. Perenyi's fluid. Czokor's cochineal. × 42.

Fig. 4. Clove-oil preparation of an embryo of about 23 days. Kleinenberg's picro-sulphuric mixture. Czokor's cochineal. × 42.

Fig. 5. Transverse section through the pectoral region, at a point indicated by the figure *5* in Fig. 1. From an embryo of 46 hours, showing the condition of the primitive layers soon after the closure of the blastopore. Perenyi's fluid. Kleinenberg's hæmatoxylin. Section is $7\frac{1}{2}\,\mu$ in thickness. × 310.

Fig. 6. Transverse section from the pectoral region, indicated by the figure *6* in Fig. 2. From an embryo of 52 hours. Perenyi's fluid. Kleinenberg's hæmatoxylin. Section $7\frac{1}{2}\,\mu$ in thickness. × 310.

Fig. 7. Sagittal section through the parietal plates, taken from the left side of an embryo of 56 hours and a little more advanced than Fig. 2. Section $10\,\mu$ in thickness. Perenyi's fluid. Kleinenberg's hæmatoxylin. × 65.

Fig. 8. Sagittal section through the protovertebral region of the same embryo as Fig. 7. × 65.

Fig. 8^a. Frontal section through the protovertebral region of an embryo a little more advanced than that of Fig. 3. Perenyi's fluid. Kleinenberg's hæmatoxylin. × 165.

fos.olf
or
vsaa
pm.pal
privs
la l
nl pibl
b
cd
cédm
cd.sp
endm
msdm
vsaa
vsaa
msidm
la l.
cœl
endm
cd sp.
vs opt
msidmax
cidm
lps

ERB del

PLATE II.

All drawings of this plate were made from transverse sections of one embryo of 72 hours. Embryo killed with Perenyi's fluid, stained with Kleinenberg's hæmatoxylin, and mounted in balsam. Sections $7\frac{1}{2}\,\mu$ in thickness. All drawings are magnified 310 diameters. The sections are: —

Fig. 9. Through the anterior region of the auditory vesicle.
Fig. 10. Through the middle region of the auditory vesicle.
Fig. 11. Through the anterior region of the first protovertebra.
Fig. 12. Through the posterior region of the first protovertebra.
Fig. 13. Through the middle of the second protovertebra.
Fig. 14. Through the middle of the fifth protovertebra.
Fig. 14^a. Through the middle of the sixth protovertebra.
Fig. 15. Through the posterior region of the seventh protovertebra.

ectdrm.
splplu
somplu
ectdrm
splplu
ectdrm
ectdrm
splplu
ectdrm
splplu
ectdrm
splplu

PLATE III.

The embryos from which the drawings of this plate are made were killed with Perenyi's fluid and stained with Kleinenberg's hæmatoxylin. Figs. 17 and 18 are from an embryo of 79 hours. The sections are about 8 μ in thickness. Figs. 16 and 19–22^a were made from an embryo of about 76 hours. Sections are $7\frac{1}{2}$ μ in thickness.

Figs. 16–18. Transverse Sections.

Fig. 16. Through the region of the auditory vesicle and fourth gill-pocket, showing right side. × 310. (See explanation of Fig. 19.)

Fig. 17. Through the middle region of the first protovertebra, showing the left side. × 310.

Fig. 18. Through the middle region of the second protovertebra, showing the right and left sides. × 310.

Figs. 19–22^a. Sagittal Sections.

Fig. 19. From the right side of the same embryo as Fig. 16. The anterior edge of the section in Fig. 19 joined the posterior (under) surface of the section shown in Fig. 16, and the planes of the two sections intersect each other at right angles. The vertical lines in Fig. 16 indicate the positions and direction of the planes of the sections shown in Figs. 19–21, and are numbered correspondingly. × 175.

Fig. 20. From the region indicated by the vertical line numbered *20* in Fig. 16. × 175.

Fig. 21. From the region indicated by the vertical line numbered *21* in Fig. 16. × 175.

Fig. 22. Through the median plane of the chorda, in the posterior trunk region. × 310. The region embraced under *A* shows a portion of the chorda in which the cells are flattened, and the nuclei are consequently arranged in planes at right angles to the axis of the embryo. *A′* (Fig. 22^a) shows the anterior portion of this region, and *A″* embraces the anterior end of the chorda, in which the nuclei are few, and have not yet arranged themselves in the vertical plane.

Fig. 22^a. Through the median plane of the chorda, showing the anterior end. This drawing is made from a part of the same section as Fig. 22. × 310. See also explanation of Fig. 22.

16
ecdrm
vs au
17
soplu.
cd.sp
cd.sp
soplu
ms'drm cap
spl'plu.
brs.brn
prvr.
19 20 21
spl'plu
ecdrm.
endrm.
coel
cd
cd.sp
18
nl
soplu
nl
spl'plu
nl'
cd
nl pcbl
endrm
nl*
ecdrm.
19
soplu
vk
cœl
spl'pl.
vs au
prvr
prvr
ms'drm cap
vk
endrm
coel
prvr
prvr
ecdrm
vs au.
spl'plu
cœl
vk
brs brn
cd.sp
22
cd
nl'
endrm
nl'
nl'
cd mo rn'
endrm

PLATE IV.

The material from which the drawings of this plate are made was killed with Perenyi's fluid, stained with Kleinenberg's hæmatoxylin; sections are $7\frac{1}{2}\,\mu$ in thickness and magnified 310 diameters. Figs. 23 and 24 are from an embryo of about 3 days, and all the others from an embryo of $3\frac{1}{2}$ days.

Figs. 23–29. Transverse Sections.

Fig. 23. Through the region of the auditory vesicle and third gill-cleft, showing the small volume of mesoderm and relatively large space occupied by the endodermal evagination forming the gill-cleft (*fs. brn.*). The sections give an anterior view on the left side.

Fig. 24. Through the region of the fourth gill-cleft, showing an earlier stage of endodermal evagination than Fig. 23, and a relatively large amount of mesoderm still in its original position.

Fig. 25. Through the region of the second protovertebra, showing the ventral shifting of the lateral layers, and nuclei (*nl.**) of protovertebral origin and some (*nl.*†) of doubtful origin.

Fig. 26. Through the posterior region of the third protovertebra, being the region in which the nephrostome is formed later, showing also the shifting of the lateral plates along the protovertebræ and the migration of cells from the lateral plates toward the median line.

Fig. 27. Through the middle region of the third protovertebra, showing three nuclei (*nl.**) under the chorda, which probably have a protovertebral origin.

Fig. 27^{a}. Through the posterior region of the third protovertebra, showing the migration of nuclei from the lateral plates toward the median line.

Fig. 28. Through the middle region of the fifth protovertebra, showing the "intermediate cell-mass" cut off from the lateral layers, and nuclei passing from its proximal margin toward the median line.

Fig. 29. Through the posterior region of the fifth protovertebra, showing nuclei from the "intermediate cell-mass" in position under the chorda.

This section represents a condition in which only a few cells have taken their place between the chorda and entoderm; but in the fourth section back of this, the mass of cells in this position is three to four cells in thickness.

24
ed.sp.
vs.au.
so'plu
ms'drm cap
car.pïèr.
nl'
brs brn
spl'plu
25
ed.sp.
vs.au
ec'drm'.
ec'drm.
ms'drm
fs.brn
so'plu.
car.pïèr
spl'plu
ed.sp
n.sp
priv
26
ed.sp
n.sp
priv
ec
so'plu
spl'plu
coel
ed
ed.
spl'plu
en'drm
coel
nl.*
nl.*
en'drm
nl.pïbl.
spl'plu
ed.mo'm'
ed.sp
27
ec'drm
priv
so'plu
nl"
nl"
ed
en'drm
nl'
28
ed.sp
priv
ec
spl'plu
ed.
ec'drm.
priv
ed.sp
so'plu
coel
spl'plu
en.
en'drm.
nl.*
nl.*
nl.tt
ed.
so'plu
priv
spl'plu
coel.
en'drm
ed.mo'm'

FRB del

PLATE V.

Material treated the same as in the case of Plate IV. Figs. 30–34 from an embryo of 84 hours. Figs. 35–37 from an embryo of 108 hours.

Figs. 30–37. Transverse Sections. (Magnified 310 diam.)

Fig. 30. Through the second protovertebra, being in front of the evagination forming the nephrostome, and showing that the somatopleure is composed of a single layer of cells.

Fig. 31. Through the third protovertebra, showing the anterior region of the nephrostome.

Fig. 32. The next section back of the one from which Fig. 31 was taken.

Fig. 33. Through the posterior region of the third protovertebra.

Fig. 34. Through the posterior region of the fifth protovertebra. The lateral portion of the intermediate cell-mass has formed the segmental duct (*dt. sg.*), and has separated from the axial portion of the intermediate cell-mass (*cl.-mo. i'm.'*). The aorta is not yet formed, and the intestine (*in.*) is not closed.

Fig. 35. Section of an embryo 24 hours older than that of Fig. 34, representing the same region. In this embryo the aorta (*ao.*) is formed as far forward as the third protovertebra. There remain in this region a relatively small number of undifferentiated nuclei of the intermediate cell-mass. The segmental duct (*dt. sg.*) is completely formed.

Fig. 36. From the eighth protovertebra of the same embryo as Fig. 35. The aorta is not yet formed. The axial portion of the intermediate cell-mass is relatively large. The segmental duct (*dt. sg.*) is formed, and the intestine (*in.*) has closed in and assumes a tubular form.

Fig. 37. From the posterior trunk region of the same embryo, showing a voluminous intermediate cell-mass (*cl.-mo. i'm.'*). The segmental duct (*dt. sg.*) is not distinctly separated from the axial cell-mass, and shows as yet no trace of a lumen. The intestine has not yet assumed its tubular form.

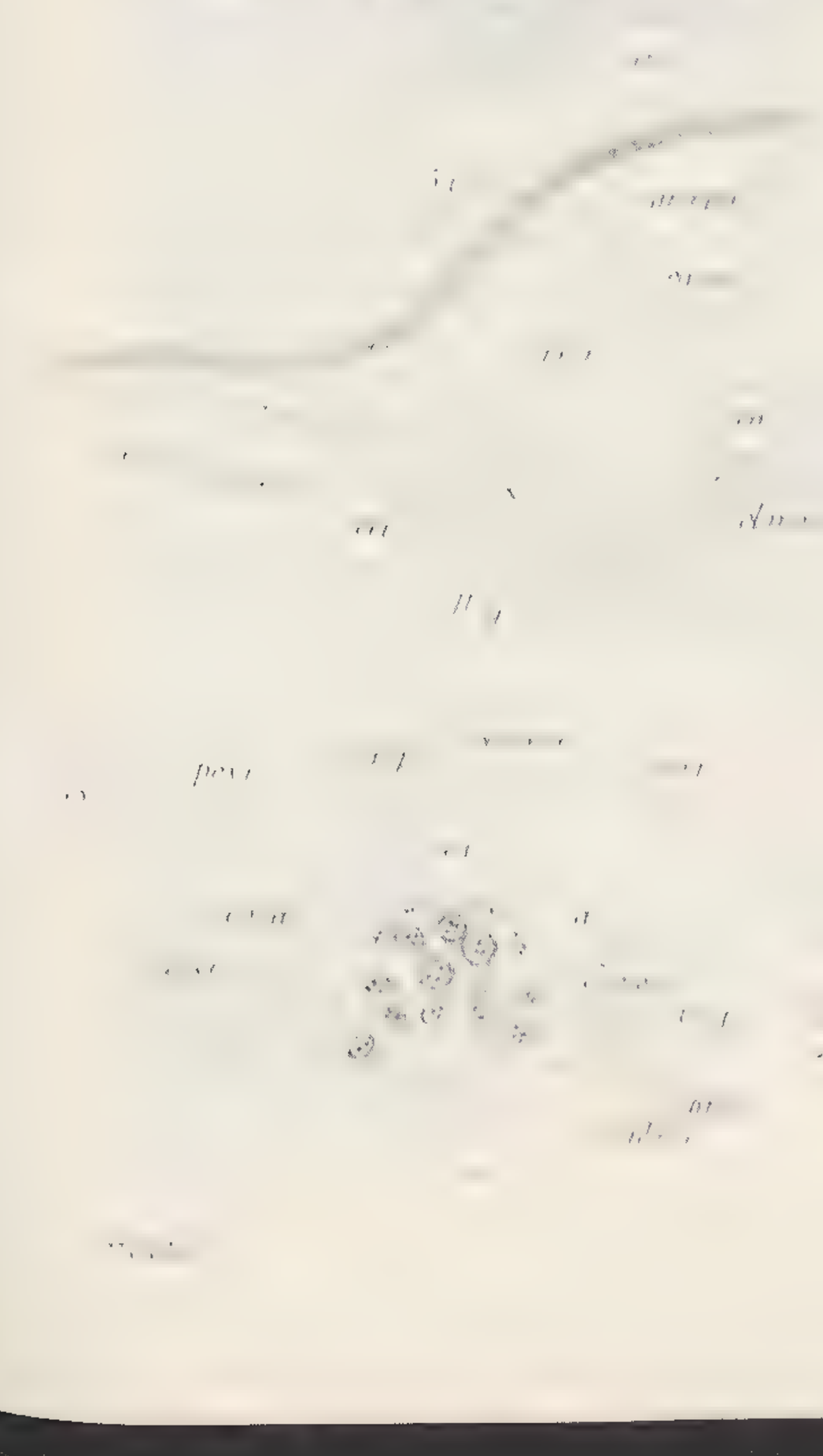


PLATE VI.

All drawings on this plate are from embryos at 96 hours. Figs. 39–44 inclusive are from the same embryo; it was killed with Perenyi's fluid and stained with Kleinenberg's hæmatoxylin. Sections $7\frac{1}{2}\,\mu$ thick.

Fig. 38. Dorsal view of a portion of a clove-oil preparation to show the relative position of the pectoral plate and the anterior protovertebræ. The principal part of the somatopleuric thickening which constitutes the pectoral plate is opposite the first four protovertebræ (*1–4*). × 65.

Figs. 39–44. Transverse Sections. (Magnified 310 diameters.)

Fig. 39. In the region immediately in front of the first protovertebra. The axial mesoderm extends laterally continuous with the somatopleure (*so'plu.*).

Fig. 40. From the first protovertebra. Here the protovertebra (*pr'vr.*) passes gradually over into the pectoral plate (*la. pct.*). The peripheral cells define the contour of the protovertebra only in its upper region. In the region of the pectoral plate no boundary of the protovertebra is distinguished. The space between ectoderm and mesoderm is due to their artificial separation during preparation.

Fig. 41. From the second protovertebra, showing the same histological connection between the protovertebra (*pr'vr.*) and pectoral plates (*la. pct.*) as is shown in Fig. 40. This section is taken from the posterior region of the (second) protovertebra, and is the tenth section ($75\,\mu$) back of the one represented in Fig. 40. The intervening sections represent the same relation between protovertebra and pectoral plate.

Fig. 42. From the third protovertebra, showing less advancement in the development of the pectoral plate than in the preceding sections, and not so firm a connection between it (*la. pct.*) and the protovertebra (*pr. vr.*). The section passes through the middle of the nephrostome (*pr'nph.*).

Fig. 43. From the fourth protovertebra, showing the pectoral plate as a single layer of cells and continuous with the somatopleure (*so'plu.*). No definite connection between somatopleure and protovertebra is shown. The section passes through the segmental tube (*tb. sg.*).

Fig. 44. From the sixth protovertebra. The somatopleure (*so'plu.*) shows no trace of any thickening to form the pectoral plate, and it has apparently no connection with the protovertebra.

E.B.B del

B.Meisel, lith. Basel

PLATE VII.

Drawings on this plate are transverse sections from an embryo of 96 hours, but somewhat more advanced than the one represented in Plate VI. Perenyi's fluid. Kleinenberg's hæmatoxylin. Sections 7½ μ thick.

Fig. 45. Through the region of the marginal vein (*vn. marg.*) in front of the pectoral plate on the right side. The marginal vein in front of the first protovertebra runs obliquely (see this region in Fig. 56); hence in sections successively nearer the tail it is seen farther from the axis of the embryo. × 310.

Fig. 46. Through the pectoral plate in the region of the nephrostome (*pr'nph.*). At this stage the lateral-line organ (*o. ln. l.*) extends backward through a portion of the pectoral region (compare Figs. 46 and 42); this is not the case in a stage slightly less advanced. The proximal region of the pectoral plate stands in close histological connection with the elements in the ventral region of the protovertebræ. × 310.

Fig. 47. Through the pectoral plate in the region immediately in front of the nephrostome. A few closely arranged nuclei below the protovertebra are from the anterior wall of the nephrostome (*pr'nph.*). The next section back shows the nephrostome, which is similar to that of Fig. 46. × 310.

Fig. 48. Through the pectoral plate back of the nephrostome, showing the elements (*pr'f. my'tm.*) passing over from the myotome into the pectoral plate. The proliferation of cells takes place both from the ventral margin of the myotome and from the peripheral layer, or muscle-plate (*la. mu.*). × 750.

Fig. 49. Through the pectoral region at the fourth section back of the one represented in Fig. 47. Nuclei (*pr'f. my'tm.*) are shown, which undoubtedly originate in the myotome, undergo rapid division, and later constitute a part of the pectoral plate (*la. pct.*). × 530.

Fig. 50. Through the pectoral region, at the next section back of that represented in Fig. 49. × 530. (Compare the relation between the pectoral plate (*la. pct.*) and the migratory cells (*pr'f. my'tm.*) of Figs. 49 and 50.)

K.B.B. del

K.Mosel... lith.

PLATE VIII.

Fig. 51. Transverse section through the posterior region of the pectoral plate of an embryo of 4½ days, being 1½ days older than the one represented in Plate VII. This section is from the region corresponding to Fig. 50, Plate VII., and shows a more complete histological connection between pectoral plate and myotome. × 288.

Fig. 52. Transverse section, sixth section back of the one represented in Fig. 51. This section is from the posterior region of the pectoral plate. × 288.

Fig. 53. Longitudinal section from the pectoral plate of an embryo of 5 days. The section passes between the vertebral region and the longitudinal ectodermic fold. The outer layer of the ectoderm is unmodified and the lower only slightly modified. The pectoral plate (*la. pct.*) extends forward to the lateral blood-vessel (*va. san.*), and backward it tapers into the single-cell layer of the somatopleure. × 288.

Fig. 54. Transverse section through the pectoral plate of an embryo of 5 days, — but slightly more advanced than the one represented in Fig. 53, — showing the beginning of the ectodermal fold (*pli. ec'drm.*) and the modification of both layers of the ectoderm. Two nuclei (*nl.*[1]) in the cuticular layer are shown which still retain in section their characteristic spindular form. × 500.

Fig. 55. Transverse section from the pectoral plate of an embryo of about 5½ days. The ectodermic fold (*pli. ec'drm.*) is more marked than in Fig. 54, and the mesodermal elements are beginning to enter it. Two nuclei (*a*, *b*) are at the base of the space included between the two layers of the folded ectoderm. × 750.

Fig. 56. An oblique frontal section from the left pectoral region of an embryo of about 4½ days. The plane of the section is higher in the axial region than in the lateral region. It shows the marginal vein (*vn. marg.*) with contained blood corpuscles, and the relation of the vein to the first four protovertebræ and to the pectoral plate. The auditory vesicle (*au.*) and the posterior gill-pocket are shown directly in front of the marginal vein. The pectoral plate, excepting its proximal region, is too high to show in the plane of this section. × 65.

Fig. 57. A transverse section through the right pectoral plate of an embryo of 6 days. The pectoral plate is beginning to shorten in the antero-posterior direction, and its contour is beginning to extend outward to form the limb-bud. In relation to the pectoral plate, the marginal vein (*va. san.*) lies father back and in a more ventral plane than in former stages. (Compare *va. san.*, Fig. 53.) × 65.

Fig. 58. A section through the limb-bud of the pectoral fin on the right side of an embryo of 7 days. The contour of the limb-bud has been carried some distance beyond the general surface of the embryo. The mesoderm has entered and closely packed all parts of the limb-bud excepting the distal tip of the ectodermal fold. The marginal vein has moved posteriorly and ventrally, and now lies directly below the limb-bud. (Compare *va. san.* of Figs. 53, 57, and 58.) × 65.

51
ec'drm
pr'vr
la pcl.
ccl
dt.sg
ra
52
ec'drm
prva
...so'plu
spl'plu
coël
dt.sg
56
au.
vn marg
1
2
3
4
ed sp
54
nl'
pla.ec'drm
la.pcl
55
la.pcl
coël.
ec'drm
va.san
58
ec'drm
au
va.san
ecidrm
pla.ec'drm
57
au
va.san
b
pls'drm

No. 3. — *On Nectonema agile, Verrill.* By Henry B. Ward.[1]

Contents

	Page
I. Introduction	135
Methods	136
II Systematic	137
III. Biology	139
IV. General Morphology	140
1. External	140
2. Internal	143
V. Anatomy and Histology	143
1. Body Wall	143
a. Cuticula	143
α Bristles	144
β Scales	145
b. Hypodermis	146
α Median Lines	146
c Muscular Layer	148
2 Alimentary Canal	151
a. Œsophagus	151
b. Intestine	154
3. Anterior Chamber	156
4. Body Cavity	158
5 Nervous System	159
a. Brain	159
α Ganglion Cells	159
β Dorsal Cells	163
γ. Fibrous Mass	166
b Ventral Nerve Cord	167
c. Anal Ganglion	169
6. Sexual Organs	171
a. Male	171
b Female	174
VI. Discussion	177
1. Dorsal Cells	177
2. Large Ganglion Cells	180
3. Rows of Hairs	181
4. Muscular Layer	181
5. Parasitic Nature	182
VII. Comparison with other Forms	182
VIII Bibliography	188
Explanation of Figures	189

I. Introduction.

For more than twenty years an interesting pelagic worm has been frequently captured at the Newport Marine Laboratory. It was probably first seen by Dr. Alexander Agassiz, who encountered it as early as 1870. His first recorded observations, made in 1871, as well as his subsequent studies, have remained, however, in the form of unpublished notes and drawings, which were placed at my disposal in June, 1891, when I began the present study. Two of these drawings, which illustrate most clearly the external appearance, and show also some of the internal organs, are reproduced on Plate I. Figs. 3, 6.

In 1873 Professor A. E. Verrill published, under the title "*gen. indet.*," a short description of two specimens captured in towing near Wood's

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L Mark, No. XXXII.

Holl, Massachusetts, and in 1879 he established a new genus *Nectonema* with the type species *N. agile*,[1] regarding it as a Nematode of uncertain systematic position.

Dr. J. W. Fewkes ('83, p. 201) was the first to figure this form; he also gave a short account of its external anatomy. But unfortunately both text and figures are somewhat inexact.

Last summer there appeared a paper by Dr. O. Bürger ('91) on the anatomy and histology of Nectonema, which placed beyond question its affinity to the Nematodes, and for the first time furnished evidence as to the details of internal structure. His work was based on material collected at Newport in 1885, but, as he himself says, it consisted of only a few specimens, and these were not in good histological condition. The gaps in his description, as well as the errors, which were largely due to insufficient and poorly preserved material, influenced me to carry out my work, which was already well advanced before the receipt of his paper. For the sake of comparison it will be more advantageous to consider under the appropriate topic the various points of structure which he describes, rather than to give a connected *résumé* of his paper at this place.

The material at command for the following study consisted of fourteen specimens, collected and preserved with great care at Newport last summer, besides those received from other persons. From Dr. E. A. Andrews I received five, which he had collected at Wood's Holl in 1890, and from Dr. W. M. Woodworth one, which was obtained at the same place in 1888. Professor Verrill, at the solicitation of Dr. Agassiz, very kindly sent me his entire collection, consisting of thirty-five specimens taken in Vineyard Sound between 1875 and 1883. For all these kindnesses, and especially to Professor Verrill for his courtesy in supplying me with personal information on numerous questions addressed to him, I desire to return my sincere thanks. To Dr. Agassiz I am deeply indebted for the hospitality of the Newport Marine Laboratory last summer, and for permission to use his notes and drawings, as well as for many other favors. To Professor E. L. Mark I owe much for valuable suggestions, and for his continued personal interest in the progress of the work.

Methods.

Nectonema is certainly an animal which it is difficult to preserve well. This is largely due to its resistent cuticula, which hinders the

[1] *N. agilis*, Verrill, '79, p. 187.

passage of most fluids. It shows, further, a strong tendency to curl in the killing fluid, thus rendering it less serviceable for section cutting. There is no reagent which does not in some cases produce a collapse of the body wall and consequent distortion or maceration of the internal organs. No reagent gave uniformly good results; the best were (1) a saturated aqueous solution of corrosive sublimate, and (2) Perenyi's fluid, heated to a temperature of about 60° C. Picro-nitric acid gave nearly as good results. The curling of the specimens may be largely prevented by straightening the worm gently with the fingers, and dropping it suddenly into the warm killing reagent. Flemming's chrom-osmic-acetic mixture made the material very brittle, even after subsequent treatment with Merkel's fluid, and is not to be recommended. Material preserved simply in alcohol, however carefully, is useful for little more than topographical work.

Bürger mentions the difficulty experienced in staining the material satisfactorily, and I agree with him fully. I experimented more than a month before obtaining a really satisfactory method of preparation; it may therefore be advisable to review the methods employed. The only carmine solution of those (8) tried which will stain it at all is Mayer's hydrochloric acid carmine, and this only after prolonged immersion. All hæmatoxylin solutions stain it fairly well, but require more time than usual. Böhmer's and Ehrlich's give brilliant results, but on the whole the latter is more reliable and can be highly recommended. The results obtained by Pfitzner's safranin are also good, and various aniline dyes are nearly as satisfactory.

In embedding in paraffin it is necessary to keep the temperature low. Series cut in paraffin of 50°–52° C. were in all respects most successful. The infiltration must be complete, but a long immersion in paraffin renders the objects very brittle.

Maceration was tried on preserved material with little success.

Great assistance was derived from the study of portions of the body cleared in clove oil before staining. Only in this way was it possible to obtain a clear idea of the structure of the two ends.

II. Systematic.

Since none of the previous observers have given an accurate description of the female, if indeed it has been seen at all, and since a more extended study has modified some of the points given in the original description of the genus and species, I have determined to restate here

the characters in synoptic form. The original description (Verrill, '79) has been followed as closely as was compatible with the changes necessitated by the discovery of the female, and by a more perfect acquaintance with the anatomy of the male.

Nectonema, Verrill, *char. emend.* — Body long, slender, nearly round. Cuticula finely ringed, on the median lines often deeply infolded and bearing on each line two rows of hair-like bristles. Bristles hollow, superficial and unconnected with each other. Head without appendages, obtusely rounded or bluntly conical with a shallow dorsiventral furrow on its anterior aspect. Mouth-opening in the centre of this furrow, minute. In the male the tail is curved ventrad, and terminates in a small conical intromittent organ. Female smaller, the posterior end slightly enlarged, abruptly truncate, with terminal vaginal (?) opening. Alimentary tract rudimentary and anus wanting in both sexes.

Nectonema agile, type species. — A long, slender, and exceedingly active round worm, resembling in form and motions a Gordius, found swimming at the surface of the sea with a rapid undulatory motion. Integument firm, opaque, smooth, except for many minute circular ridges interrupted at the median lines, which are themselves often thrown into larger, deeper folds, locally very prominent. Body in life round, of nearly uniform size throughout, tapering slightly close to the head, and somewhat more towards the posterior end in the male. Each median line is distinguished by two narrow longitudinal bands of minute dots between which stand two longitudinal rows of hair-like bristles. The worm undergoes torsion in the anterior third of the body, so that the median lines appear lateral in the posterior two thirds of the body. The double row of bristles extends from a point 1 or 1.5 mm. behind the apex of the head to about the same distance from the posterior extremity of the body. The bristles are 0.3 mm. in length, opposite to each other, hollow, unconnected by any web, entirely superficial, and hence easily detached and often injured or lost over considerable stretches of the body. The head is marked anteriorly by the presence of a shallow median dorsiventral furrow, on each lateral edge of which are one, sometimes two, low rounded papillæ. The anterior portion of the body is semi-transparent, externally not separated by any constriction from the rest of the body; but internally an anterior chamber is divided from the general body cavity by a partition which is concave anteriorly. The anterior chamber is traversed by the œsophagus, and contains ventrally the brain, while the dorsal space is filled by four large conical cells which send processes down into the nervous matter of the brain. The œsopha-

gus is lined by a minute chitinous tube, which is intracellular in position, and after forming a loop opens out into an intercellular intestine that is highly degenerate posteriorly and in the adult lacks a terminal opening. The posterior end of the male is a ventrally curved conical intromittent organ with a terminal opening. The female is provided with a terminal bulb having a central cloacal (?) opening. The small spherical eggs are filled with large refractive yolk granules and protected by a shell, the thickenings of which become long and pointed spines on coming in contact with the water. The eggs measure 36–40 μ in diameter without the spines, which are 8 to 10 μ long. Color of the animal in life grayish to yellowish white with transparent anterior end. The median lines each show two narrow longitudinal bands of dark slate color.

Length of the male, 50 to 200 mm.; of the female, 30 to 60 mm. Diameter, 0.3 to 1 mm.

Habitat: Narragansett Bay, R. I., A. Agassiz (1870–90), J. W. Fewkes (1883); Vineyard Sound, Mass., S. I. Smith (1871), A. E. Verrill (1879); Wood's Holl, Mass., W. M. Woodworth (1888), E. A. Andrews (1890).

III. Biology.

Up to the present time Nectonema has been reported from two places only, Newport, R. I., and Wood's Holl, Mass., and the south shore of New England may fairly be considered as its home. Here it is not so rare as has been supposed, for by systematic search fifteen specimens were secured in one summer. The dates of capture of some sixty-five specimens show that it may be found from the last of June to the first of October,[1] with two maxima, one in July and a second in September, more than two thirds however having been caught at the earlier date. It is noteworthy that, of the fifteen individuals captured at Newport last summer, all were taken while the tide was going out, and on evenings when there was no moon, the ordinary time of towing being between 8 and 10 P. M. The latter circumstance seems to indicate that the worms are susceptible to light; the possible significance of the former will be discussed later. It is also an interesting fact, that they were caught in towing near the shore, two in fact having been dipped up one evening in July when filling a pail with water at the landing of the

[1] I do not believe that towing has been done in this region with any regularity at other times of the year, so that these dates cannot be accepted as fixing the time of its occurrence.

laboratory, which is located on a small cove near the mouth of Narragansett Bay.

When first caught they were very active, swimming vigorously from side to side of the vessel into which the tow was emptied, and trying alternately the surface and the bottom of the water. Their motions are of two kinds; first, a rhythmical movement, evidently caused by progressing waves of muscular contraction alternating on the two sides of the animal; and, secondly, a more violent motion, which consists in first coiling the body into two large successive loops, and then straightening it suddenly and coiling it at once in the opposite direction. In this way the worm assumes much the general appearance of a figure ∞. By the first kind of motion it makes rapid and definite progress; but the purpose of the latter did not seem to be *locomotion*; it was rather relief from some irritation, which on one occasion was apparently a mass of foreign matter which had accumulated on the bristles. These, together constituting what has been called the lateral fins, can ordinarily be easily seen even during the motion of the animal, and evidently are not actively concerned in its movements.

Nectonema always swims with the translucent end, which, as will be seen later, is the head, in advance. How long the activity exhibited at first persists, I do not know. The animals captured in the evening were usually found on the following morning resting on the bottom of the dish, and exhibited only occasional fits of activity. This may have been due to the effects of light or of captivity. I am inclined to consider it to be the result of the latter, since usually before noon of the first day after capture the worms voided into the water masses of eggs or spermatozoa which were often unripe, and then became more and more sluggish. But the material was too valuable to warrant the risk of its becoming injured for histological purposes by longer delay, and observations were therefore terminated at this point by killing the animals.

IV. General Morphology.

1. External.

Nectonema is in life of an opaque grayish white with semi-transparent ends. The body is perfectly round and the median lines show no trace of the flattening described by Verrill and Fewkes, and so often seen in the preserved specimen. This condition is unquestionably the result of collapse. The general surface of the body is smooth, except for the many

fine circular striations which are so characteristic of Nematodes in general. Here however the striations are interrupted by the median "lines,"[1] whose smooth surface is marked off more or less regularly by deep furrows which extend transversely, yet only across the line itself. These lines may be seen to start near the anterior end of the body on its dorsal and ventral surfaces. Owing to a gradual torsion of the anterior third of the body, they are brought at the end of this portion into a lateral position, which they preserve throughout the rest of their course, i. e. up to a short distance from the posterior end. This apparent change in position is diagrammatically represented in Figure 1[a]. They are really the median lines, though their position throughout the greater part of the body caused them to be described at first as the lateral lines. Each of them is limited on either side by a narrow dark-colored border which under a high power resolves itself into a crowded mass of deep-seated dots (Fig. 7). Between these two marginal bands, on the lighter portion of each median line, are located in a double row the characteristic bristles. Their arrangement and structure will be considered later.

It is the deep furrows in the median lines together with the dark borders they transsect which produce the "squares marked in outline by black pigment" described by Fewkes ('83, p. 201). The transverse furrows appear and disappear with the movements of the animal, while the squares vary both in form and size (Fig. 7) and are due merely to the folding of the lines necessitated by the contraction of the adjacent muscular areas, as Bürger ('91, p. 636) has shown. They have, then, nothing to do with internal segmentation, but are purely mechanical in their origin.

The length of the males that I have examined varies from 32 to 130 mm.[2] Of the seventeen which were measured exactly, only three were less than 55 mm. long, and the same number were over 100 mm., the most of the rest being close to the average, 68 mm. The diameter of the male varies at the head from 0.32 to 0.65 mm., at the middle from 0.4 to 0.75 mm., and just in front of the terminal papilla from 0.2 to 0.4 mm. The three females caught measured 34, 38, and 40 mm. in length, and at the regions of the body mentioned above on the average 0.35, 0.45, and 0.25 mm. in diameter. Thus, excepting the imperfect specimen men-

[1] The name "line" seems to be peculiarly inappropriate as a designation for these broad bands, but I have used it in the technical sense in which it has been employed for Nematodes in general.

[2] There was but one male less than 45 mm. in length, and this one must also have been nearly as long, since the head and a portion of the body were gone.

tioned above, they are shorter than any of the males, though in diameter intermediate between the extremes of the latter. The only female among the specimens sent by Professor Verrill measured 60 mm., which still is shorter than the average male, and far below some of the large males in that collection, one of which reached even 200 mm. in length.

Not only is the female smaller than the male, but also far less plentiful. Among the sixty-five specimens which I have examined, there were but four females, a proportion so small as to suggest that it is due in part to other causes than the greater number of males produced. Possibly the female, being the less active of the two, is not so often at the surface, and consequently is less frequently caught.

From the general external appearance one easily recognizes three main parts of the body, a short semi-transparent anterior portion, a very long opaque middle region, and a terminal part, which resembles in transparency and length the anterior portion. The anterior region goes over into the body proper without any external demarcation. There is no constriction at this point in the living animal, and although one is usually found here in alcoholic specimens, it is surely the result of contraction or collapse. If, however, the living animal be studied under a compressor (Fig. 2), or still more clearly if the anterior part of the body of an alcoholic specimen be examined in clove oil, this clear portion is seen to be cut off from the general body cavity by a transverse partition (Plate I. Fig. 8), thus forming an anterior chamber, which will be considered in detail later.

Following this the body proper is uniformly opaque in appearance, and constitutes the greater part of the entire length, passing over insensibly near the posterior end of the body into the posterior translucent region, which is however by no means so clear as the anterior part. The body terminates in the female abruptly, but in the male it is prolonged into a ventrally curved conical organ with a terminal opening. The general appearance of the worm is shown in Figure 1, which represents in its natural size one of the largest specimens captured. The difference between the posterior end of the male and that of the female is easily seen by comparing views of the two as seen under a dissecting miscroscope (Plate I. Figs. 4, 5). The female is represented in the act of discharging eggs. The end of the body of the male differs greatly in appearance in different individuals. It may be nearly straight with only the intromittent organ turned slightly ventrad (Fig. 89), or for a greater or less distance anterior to this point it may be flexed ventrally or even coiled (Fig. 1). The end of the female is on the other hand nearly straight,

slightly enlarged, and blunt. The centre of the blunt surface shows the terminal orifice, from which the eggs are being voided.

The general external surface, more particularly on the lines and about the rows of bristles, is often covered with minute algæ and dirt. A similar mass frequently envelops the posterior end, making the determination of its character a difficult matter, especially in the case of the female, if an egg mass be protruding from the opening. It may have been such an appearance which caused Verrill ('79, p. 187) to describe the female as possessing a small terminal papilla.

2. Internal.

The general plan of the internal anatomy may be easily understood from any cross section (Fig. 11). Passing from the surface inward, the thick cuticula is followed by a thin hypodermis, beneath which is the highly refractive muscular layer. The protoplasmic ends of the muscle cells, together with other elements, form the layer immediately surrounding the body cavity. Dorsally and ventrally the muscular layer is broadly interrupted by the prominent median lines. The body cavity contains in a varying position the alimentary canal, which is strikingly small and sometimes wanting. A sac-like organ varying in size hangs from the dorsal line into the body cavity, which may also be filled with generative products. The ventral line encloses the ventral nerve cord. A comparison of the various figures will show the variation in the proportions of the ventral line at different points in the body and in the two sexes.

V. Anatomy and Histology.

1. Body Wall.

In treating of the finer anatomy I shall consider first the structure of the part under consideration in the male only, and at the end of each section give a comparative account of its character in the female.

a. Cuticula.

The cuticula, which covers the entire body and is continuous with the lining of the œsophagus and of the terminal sexual opening, is of nearly equal thickness throughout, averaging 3 μ on the side of the body, being however perceptibly thicker (about 4 μ) over the median lines. On top of the anterior chamber it is only 2 μ thick, which partially explains the transparency of that region. At the front of the head, on the other

hand, it measures from 5 to 10 μ in thickness. It is highly refractive, and similar to chitin, although not identical in composition with that substance, since it may be easily dissolved in boiling KOH. Occasionally one notes a fibrous or lamellar structure, the layers being parallel to the surface. In most places an outer extremely thin layer may be easily distinguished from the subjacent portion by its higher refractive power. The inner surface of the cuticula is not always even and clearly marked off from the hypodermis, but frequently shows a jagged outline with underlying granules, which decrease rapidly in size toward the muscular layer.

On the front and upper surface of the head one finds occasional fine pore canals, and in total preparations short hairs were seen, but no connection between the two could be established. In the hollow produced by the ventral flexion of the posterior end, the cuticula displays a curious peculiarity. The highly refractive outer layer remains intact, but the inner layer is, as it were, bored with conical holes, into which the hypodermal tissue projects. These probably represent sensory organs, but in spite of the proximity of the anal ganglion a nervous supply could not be demonstrated.

There are present as structures of undoubted cuticular origin the hairs or bristles of the lines and peculiar scales found along the posterior portion of the body of the male.

The *bristles* (Fig. 72) form a double row along the dorsal and ventral lines, beginning only 0.2 mm. behind the transverse partition which cuts off the anterior chamber, and extending to within 0.5 mm. of the posterior end of the body. The two rows are only 15 to 25 μ apart, and the bristles stand opposite each other (Plate II. Fig. 12) at regular intervals of 10 μ. Normally they are entirely unconnected by any web of tissue or mucus. They are, moreover, but lightly attached to the cuticula, and hence easily broken off, so that even in the living animal it is rare to find any considerable tract perfect. One can usually see the scars that have been left, and apprehend from these the normal relation of the bristles. Each bristle is, when perfect, about 0.3 mm. long and hollow, having in cross section (Fig. 13) an external diameter of 5 μ and an internal one of 2 μ. The base is slightly enlarged, and rests on the cuticula (Fig. 13), from which in sections it is separated by a definite line of demarcation. From the base the bristle tapers very gradually to a fine point. Its cavity is simply rounded off at the base, being separated from the cuticula by a thin layer; toward the point its cavity gradually disappears. These structures are, then, entirely super-

ficial, and evidently cannot be actively moved by the animal. They are in all respects carefully to be distinguished from the setæ of Annelids, with which they have nothing in common. Bürger ('91, p. 634) called attention to the fact that the hairs are hollow, and are purely cuticular structures.

Scales. — One finds on the sides of the male near the posterior end numerous scale-like cuticular outgrowths. My attention was first attracted to them in transverse sections, where they present the appearance of a tooth (Plate II. Fig. 14). Seen from the surface (Fig. 18) they have much the shape of a clam shell. They are found scattered over both lateral aspects of the animal, in spots so thickly that from one to seven are cut in each transverse section (Fig. 14). They vary much in size, the smallest occurring near the beginning and end of the area, whereas they are interspersed with larger ones at the centre. The area which they occupy begins about 1.2 mm. from the posterior end of the body, and extends over 5 to 10 mm. In general such a scale may be said to resemble a narrow clam shell attached along the hinge side (Fig. 18). The line of attachment is always parallel to the long axis of the body, but the concavity of the scale is directed indiscriminately dorsad or ventrad (Fig. 14). The length of the scale is about 40 μ, its height averages 15 μ, and the thickness varies from 7 to 8 μ.

In most transverse sections the external layer of the cuticula is continuous over the entire surface of the scale (Fig. 15), and only in certain cases can one see that it is interrupted by a minute opening (Fig. 16), which is connected with a fine canal. On account of its minute size this canal can be traced through its entire length only in exceptional cases, and usually appears as a groove at the outer or inner margin of the scale (Fig. 17). I was unable to find either gland cell cónnected with the canal or sensory filament passing through it.

The core of the scale is formed of a substance which stains like the internal layer of the cuticula, but which is in nearly all sections well marked off from that layer. If the scales be treated with caustic potash, the core is broken up into lamellæ by lines which radiate from the apex of the scale. In transverse sections, however, the core is marked by fibres parallel to the central canal, and thus nearly perpendicular to the fibres of the internal layer of the cuticula elsewhere. This difference in the direction of the component fibres serves to separate the core of the scale from the internal layer of the cuticula in and near the plane of the central canal (Fig. 17), whereas elsewhere one finds no definite line of demarcation between the two (Fig. 15)

It is difficult to believe that this canal represents merely the central protoplasmic core upon which the scale was formed, since, if this were the case, it would be closed terminally by at least a thin layer of cuticular substance. But this is not the case. The opening is always larger and plainer than the canal itself, which is too narrow to be measured.

These structures are entirely lacking in the female. Their occurrence in the male alone, and over only a limited area near the posterior end, suggests connection in some way with the sexual act. If it be the case here, as in Gordius, that the male grasps the female during copulation by winding itself about the posterior portion of her body, the use of these scales in holding on to the cuticula, which differs from that of Gordius in being smooth, is at once suggested. The canal may then be either the duct of a gland or a tactile organ.

The cuticula of the female is nowhere more than 1 μ thick, and precludes thus any profitable study of its structure. The bristles are present, and do not differ materially from those of the male. They are, however, somewhat more slender and shorter. The scales of the male are entirely lacking, and no analogous structures were found.

b. Hypodermis.

The hypodermis, or subcuticula, as it is often called in Nematodes, forms immediately under the cuticula a layer of comparatively uniform thickness and structure, being, however, peculiarly modified in the anterior chamber, in the median lines, and in the terminal organ of the male. Its modifications will be considered under the organs in question. Sometimes no trace of this layer can be found, but in the majority of sections it can be demonstrated in some places.

The hypodermis (Fig. 20) normally appears as a narrow granular layer 7 μ in thickness, without cell walls, but containing numerous prominent nuclei arranged somewhat regularly, and characterized particularly by the indefinite distribution of their chromatic matter and the faint, uncertain way in which they are stained. It is separated from the underlying muscular layer by a delicate basement membrane, which ordinarily cannot be demonstrated, but which is easily seen where the muscle cells are shrunk apart or torn away.

Median Lines. — The hypodermis appears to be highly differentiated in two regions, the dorsal and ventral lines, where it becomes so much thicker as to cut down into the muscular layer and separate it into two lateral areas. These lines were regarded by Verrill and Fewkes as lateral; but, as Bürger has clearly shown, they undoubtedly correspond

to the median lines of other Nematodes. The curious torsion, by which in the normal position of the body they come to lie laterally for the larger portion of its length, has already been described.

The two lines, dorsal and ventral, are very similar in form and structure (Plate VIII. Figs. 101, 102), except that the ventral line contains the prominent ventral nerve cord, which will be described in connection with the other portions of the nervous system.

The *dorsal line* can first be seen distinctly immediately behind the partition which cuts off the anterior chamber. In front of this I find no dorsal differentiation of the hypodermis, and consequently no dorsal line. At its anterior end the dorsal line has a thickness of 20 μ; passing posteriad, this gradually increases to 40 μ, and this thickness remains nearly constant until within a short distance from the end of the body, where it becomes gradually reduced and finally disappears. The line is separated from the body cavity by a prominent basement membrane, the direct continuation of that which separates hypoderm and muscular layer. The elements which make up the dorsal line (Fig. 102) appear both in longitudinal and in transverse sections as a row of elongated cells, the walls of which are usually first visible a short distance below the cuticula, although in one specimen preserved in Flemming's mixture they could be traced even up to the lower surface of the cuticula itself. The nuclei are oval, poor in chromatic substance, hence pale and not at all prominent. They lie with the long axis perpendicular to the surface of the body, nearly or quite filling the entire diameter of the cell. In most cases they are found at about the same level in the different cells, which thus form a regular epithelial layer. The deep ends of the cells are prolonged into processes which extend down to the basement membrane through a mass of fibres which cross in every direction. Among this net-work of fibres in the lower portion of the line one finds occasional cells with branching processes (*, Fig. 102), which may be nervous. There is however no definite nerve cord extending through the line, and no evidence was found of the connection of these cells with other parts of the nervous system.

The *ventral line* is similar in structure to the dorsal line, in that it consists likewise of a layer of high cells of an epithelial character immediately underlying the cuticula (Fig. 101). Their deep ends are also prolonged into processes, which are here bent around the ventral nerve cord, which lies in the centre of the line. Between the cord and the basement membrane below is seen again a confused mass of fibres, into which, as in the case of the dorsal line, the deep ends of the cells

pass. The boundaries of the epithelial cells extend in this case also only to within a short distance of the cuticula ; they cannot ordinarily be traced up to it, except, as in the case of the dorsal line, in material preserved in Flemming's mixture. The entire ventral line is separated from the body cavity dorsally, and from the muscularis on both sides, by a basement membrane.

In the adult female the lines do not exceed 8 μ in width, and are consequently difficult to study, but I think the same elements can be seen, though not so clearly as in the case of the male.

Bürger ('91, p. 636) believed the collection of long cells at the apex of the head to be a part of the dorsal line. I can find no special connection between the two regions, and no striking similarity in structure. The shallow groove which he believed characteristic of the external surface of the dorsal line is not present in the living animal. It is undoubtedly the effect of collapse, since it is found only in preserved specimens. I did not find the large cells which he says occur at regular intervals in the dorsal line. Perhaps they are found only in individuals of a certain age, or they may be connected with the formation of the hairs. Proof of the existence of a columnar epithelium, which he conjectured to be present, has been given above.

c. Muscular Layer.

In cross sections of the body the muscular layer presents two sharply marked portions, a peripheral, radially striated zone (Plate I. Fig. 11) and a deep protoplasmic region. Along the line of union of the two lies a double or triple row of thickly crowded nuclei, and in some regions, or under certain conditions, other nuclei are found scattered through the protoplasmic portion. The relative thickness of the two zones varies greatly. In the most of the specimens which I cut they were of nearly equal breadth, but in some the protoplasmic zone was more than twice as wide as the striated portion, and in other cases not half so wide. These conditions are represented somewhat diagrammatically in a number of transverse sections (Plate II. Figs. 23 to 26), which are taken from different individuals.

The general meaning of the two zones is at once apparent. The striated portion is made up of the contractile fibres of the muscle cells ; the protoplasmic area represents the non-differentiated portions of the same cells together with certain other elements. I met with indifferent success in attempting to make macerations of this region and I am not able to affirm definitely what proportion of the protoplasmic zone is

made up of the ends of muscle cells and to what extent it is formed of other elements. Certain it is that this zone contributes to the formation of at least a certain number of other elements: this may be by a differentiation from the protoplasmic body of the muscle cell, or it may be that the elements have no genetic connection with the muscle cells. In order to discuss this question it will be necessary first to consider carefully the structure of the individual muscle cell.

For this study the region near the dorsal or ventral line is very favorable, since here the cells are shorter and broader than elsewhere, and thus it is easier to trace the cell walls. Cross sections of this region (Plate II. Fig. 21) show with perfect clearness that each muscle cell is composed of two portions, corresponding in appearance and position to the two zones of the muscular layer. The highly refractive peripheral portion is seen in longitudinal section (Fig. 22) to consist chiefly of fibrillæ; these are, however, developed only at the periphery of this portion of the cell, the core of which is composed of a finely granular protoplasm. The latter is directly continuous with the granular protoplasm of which the deep-seated part of the cell is exclusively composed and in which the nucleus is located. This is the condition of the typical muscle cell of the "Cœlomyaria." In the centre of the muscular layer, i. e. in the lateral walls of the body, the cells diffe. only in being much deeper and more flattened. From maceration preparations (Fig. 22) it may be seen that the inner or deep margin of the band of fibrillæ is bounded by a very thin layer of protoplasm which at intervals is continued downward into the elongated cell body. This is also seen in transverse sections (Figs. 28–30). It would seem (Fig. 22) as if each muscle cell had more than one protoplasmic prolongation, but since I was unable to ascertain the length of the individual cells this cannot be positively asserted.

The nuclei usually lie just below the contractile portion of the cell. They are oval, and each has a thick nuclear membrane, which stains deeply, but encloses very little stainable substance, the numerous nucleoli being minute and faint. There are also at times unquestionably as many as two nuclei in each protoplasmic projection, and in certain specimens it was common to find nuclei far down toward the deep end of the cell.

I must call attention in this connection to some very peculiar nuclei which were found among the nuclei of the muscle cells, but which differ from them strikingly (Fig. 27). They were usually located rather more distally than the others, and each showed a tail of varying length, which

projected far up among the contractile fibrillæ. Tailed nuclei have been found by various observers, and sometimes the form has been attributed to mechanical injury in cutting. But this cannot be the case here, since they were plainest in sections 20 μ thick at a level distinctly between the two surfaces of the section. From the general appearance of the sections I doubt the probability of the form being due to pressure in killing or preparing, and am inclined to regard their form as normal. Such nuclei have been explained as nervous; the only argument which can be said to favor that view in this case is their position, and the absence of other known nervous terminations in the muscular layer.

The striated zone is narrow in the anterior chamber and at the posterior end of the body, but is elsewhere of nearly uniform width in any one specimen. It remains entirely colorless in carmine stains, but takes up hæmatoxylin with avidity and does not give it up in acid fluids.

The protoplasmic portion of the muscular cell is highly granular and ordinarily does not stain at all. In the protoplasmic zone, however, there are cells which stain in eosin much deeper than the remaining elements (Fig. 29, *x*). The contents of these cells are so finely granular as to appear almost homogeneous. Lying in the body cavity near these cells are corpuscles, which in general appearance and affinity for stain are identical with them. It will appear probable, I think, from the figures given (Figs. 28–30), that these corpuscles are derived by abstriction from the deeply staining cells of the protoplasmic zone. They are found of all sizes, but never in very great numbers. There is some evidence to show that the deeply staining cells are the proximal ends of certain muscle cells, the contents of which are perhaps chemically altered; the corpuscles, however, never contain nuclei, so far as I have seen. In view of the evident correlation between the thickness of the muscular wall of the body and the sexual maturity of the animal, it is possible that the function of these corpuscles is nutritive. This will be discussed in connection with the description of the sexual organs.

Evidence which goes to prove the formation of true cells from this layer is obtained from the study of the female in which the eggs were in the most immature condition of any which I had. Here (Plate IV. Fig. 59) sections show the body wall to be composed of the layers already described, except that the protoplasmic portion of the muscle cells is much shorter, and there seem to be proportionally fewer nuclei and fewer cells than in the sections previously described. In addition

to these there is, however, the remnant of a deeper layer. Certain cells (*, Fig. 59) project into the body cavity; they are homogeneous and lightly stained, in opposition to the muscle cells which remain unstained, and they contain nuclei at the proximal end of the cell. In the body cavity of this specimen were found, in addition to the eggs, cells of a very similar appearance to these, and at points along the wall of the body cavity flattened cells had arranged themselves in the form of an epithelium. All these points naturally suggest that this layer is concerned in the production or nourishment of the sexual cells, and that the remnant of the layer is in process of forming itself into a secondary epithelium. The evidence is however too incomplete to justify more than a suggestion; but it points strongly to the existence of more than one kind of histological element in the protoplasmic zone of the muscular layer.

The foregoing description of the muscularis differs essentially from that given by Bürger ('91, p. 635). Especial attention must be called to the fact that the relative thickness of protoplasmic and contractile portions as he gives it, namely, 2 : 1, is true in only one of the sections he figures (Taf. XXXVIII. Fig. 5), whereas others of his sections (Figs. 3, 4) represent exactly the opposite extreme.

2. Alimentary Canal.

a. Œsophagus.

Attention has already been called to the fact that one finds a shallow dorsiventral groove (Fig. 2) at the front of the head, and that the minute mouth opening is located at the centre of this groove (Plate V. Fig. 63). The cuticula, which is extremely thick at this point, is here infolded; the deep layer extends but a short distance, while the external layer is continued backward to form the œsophageal tube. Here as elsewhere this layer is highly refractive, and has walls 2 μ thick, enclosing a lumen only 3 μ in diameter. The deep layer, which surrounds the beginning of the œsophageal tube, measures 9 μ in thickness. After this layer stops, the chitinous œsophageal tube, which is the continuation of the external layer, becomes somewhat thicker, and it is seen that the entire tube is contained within a cell of small diameter (Plate III. Fig. 32). From longitudinal sections it is seen that the cell is coextensive with the tube; at least there are no transverse cell boundaries, though throughout its length one finds many nuclei which lie closely packed together. In transverse sections the nuclear matter

appears fragmented, and usually has a more or less concentric form surrounding the tube (Fig. 50). That face of the nucleus which is turned toward the tube is less regular than the other, and usually shows a broken and less sharply marked contour than elsewhere. The amount of chromatic substance, large in proportion to the somewhat meagre supply of protoplasm in the cell, is also noticeable.

The œsophageal cell with its contained tube traverses the anterior chamber; from the mouth opening it first passes through the hypoderm, then it lies in a groove on the dorsal surface of the brain (Plate VI. Fig. 73), and later is spanned by the dorsal commissure (Fig. 80), directly behind which (Fig. 81) it extends a short distance free until it reaches and pierces the transverse partition (Plate I. Fig. 8). It is enveloped throughout its course by the same peritoneal membrane which lines the anterior chamber. The occasional flattened nuclei of this membrane may be seen at intervals on the outside of the œsophageal cell, even where the latter is surmounted by the dorsal commissure of the brain.

Before tracing the further modifications of the œsophageal cell, it is interesting to note one or two points of variation in the portion already described. Although the tube is commonly of uniform caliber and open from end to end, this is not always the case. Figure 50 (Plate III.) shows a cross section of the œsophageal cell 0.1 mm. from the apex of the head. Here the tube is of the usual appearance, but a few sections farther back not only lumen, but tube as well, has disappeared (Fig. 51). Some distance farther posteriad the tube appears again, but as a solid cord, which, however, acquires a lumen at a point 0.4 mm. from the apex of the head, and from this place on preserves its ordinary character. Furthermore, variations in the diameter of the lumen are common. The important physiological bearing of these features will be discussed subsequently.

The œsophageal tube and cell enter the partition and pass through with only a slight expansion in the size of the cell (Plate V. Fig. 63). Bürger has figured and called attention ('91, p. 643) to the presence of a strong dorsal bend of the tube within the partition. This is assuredly abnormal, since it is found but rarely. It is entirely wanting in the other individual figured by him (Taf. XXXVIII. Fig. 1). When present it is probably *on*, not *in*, the partition, and is evidently due to the ventral flexion of the œsophageal cell and tube resulting from the forcing forward of the partition in preservation. This wall is in life concave anteriorly, and it will be clear at once, from a glance at Figure 3, that, if at

any time in the course of manipulation a change to a denser fluid be made too suddenly, the result will be to force the partition forward, and consequently to bend the œsophagus in the space between the brain and the partition, where it is free from supporting tissue. Exactly this is shown to have happened, only in a less degree, in my Figure 8.

Following now the course of the œsophageal cell after it emerges from the partition into the general body cavity, one finds a second cell alongside of it (Plate III. Fig. 33, *cl. in.* I.), which resembles it in the entire absence of transverse cell boundaries and in the presence of many nuclei, but is unlike it in the highly granular condition of the protoplasm and in the shape and appearance of the nuclei. Since the intestine hangs free in the body cavity, the position of the cells can be determined only in a general way. The new cell, which may be named the first intestinal cell, lies approximately lateral to the œsophageal cell (Fig. 33). It begins at about 0.8 mm. from the apex of the head; about 0.4 mm. farther back, a second intestinal cell (*cl. in.* II., Fig. 34) is added. This lies nearly ventral. A third cell (*cl. in.* III., Fig. 35) begins 1.3 mm. from the apex of the head, and a fourth (*cl. in.* IV., Fig. 36) 0.1 mm. farther posteriad. This completes the number. The œsophageal cell, which may be recognized by the presence in it of the cross section of the chitinous tube, now lies lateral to the four intestinal cells (Fig. 36), but soon wedges itself in between two of them until it reaches the centre of the group (Fig. 43), and then suddenly ends, leaving a cavity (Fig. 44) surrounded by the four intestinal cells which have accompanied it a longer or shorter distance from their origin.

It is now necessary to ask how the chitinous tube is concerned in these changes. Up to the point where the fourth intestinal cell is added, it remains a straight simple tube. Shortly beyond that point it makes a complete turn upon itself (Plate I. Fig. 8), and from a lateral position with reference to the four intestinal cells it reaches a median one (Plate III. Figs. 37–43).. Hence the loop lies in that portion of the œsophageal cell which is wedged in between two of the intestinal cells (Fig. 38), and almost completely fills the space. The tube proceeds a short distance farther, 60 μ only, tapers to an exceedingly fine point, and opens out into the space which has arisen between the four intestinal cells (Figs. 8 and 44). This space is the intestine proper, and justifies the application of the name "intestinal cells" to those elements which, though originating farther forward, were destined to bound it. These relations, which are evident in every complete series through this region, are represented in a succession of figures taken from one series of

transverse sections at short intervals (Figs. 31–44). The general form of the tube may also be seen in the optical section represented in Figure 8.

The œsophagus varies from 0.75 to 1.5 mm. in length, being from $\frac{1}{40}$ to $\frac{1}{90}$ of the total length of the worm. The loop which occurs near its posterior termination measures from 50 to 100 μ in length, and from 20 to 30 μ in width. It lies nearly in the sagittal plane, and ventral to the general course of the œsophageal tube. The absolute uniformity of its occurrence and the normal appearance of the adjoining intestinal cells preclude the idea that this is an accidental fold. It must be regarded as a normal yet very curious feature of the œsophagus.

b. Intestine.

The intestinal cells, which, as has been shown, are first encountered on the œsophageal cell just behind the partition, are four in number at the point where the intestinal cavity is formed and the œsophagus opens into it. These four however clearly constitute two pairs which are unlike (Fig. 37). The contents of one pair is a coarsely granular plasma, whereas that of the other pair is finer. The first remains unstained in hæmatoxylin, but takes up enough hydrochloric acid carmine to give the plasma a reddish tinge. The reverse is true of the other pair of cells. Occasionally the granules in the first pair of cells become very coarse, and then appear like excretory secretions. As already mentioned, there are no transverse partitions dividing the cell (Fig. 52), although a very large number of nuclei are present, usually several in each section (Fig. 39). Only two of the four cells are represented in Figure 52, which is a surface view. The differences in the character of the nuclei are well shown in the figure.

The walls of the intestinal cells are very strong, perhaps even cuticular, since they remain intact long after the cell contents have been completely macerated out. There is however, no special chitinous lir ing for the intestine, such as Bürger has figured ('91, Taf. XXXVIII. Figs. 25, 29). This appearance is probably due to the partly macerated and detached membranes of the adjacent cells.

The portion of the intestine bounded by four cells is relatively short. One of the finely granular cells[1] dwindles down to a point (Fig. 45) and a new one takes its place. This pushes itself obliquely under the adjacent coarsely granular cell on one side, so that the latter is excluded

[1] Owing to a break in the series figured, I am unable to state positively which one of the original four is the first to disappear.

from participating in the boundary of the lumen, which is now limited by only three cells, one dorsal and two ventral. The cell, thus forced back from the lumen, dwindles away, and is not replaced by another.

A lumen bounded by three cells persists for some distance backward, but finally another cell disappears and the lumen lies between two cells (Fig. 49). I did not succeed in finding the exact spot where the disappearance of the third cell takes place, and am hence unable to give the details of the process. From this place posteriad all further change is of degree and not of kind, since the intestine simply grows smaller, the lumen all but disappears (Figs. 46–48), and finally the whole structure vanishes (Fig. 9) shortly before the end of the body is reached. In no case, either in entire preparations or in sections, was I able to trace it nearer than within a few millimeters of the posterior end of the body; and since it was entirely free at its termination, no clue was given as to its relation to the terminal orifice of the body. Since this orifice is clearly connected with the sexual organs, as will be demonstrated later, it remains doubtful whether it is a cloacal opening, or whether the end of the intestine is to be found elsewhere. Certain it is that in the intestine we have a highly degenerate organ, so that from a study of the adult alone no light can be gained as to its termination. It is interesting to note that the œsophagus is intracellular, the intestine however clearly intercellular.

No mesenteries were found binding the intestine to the body wall, and consequently its position varies in different individuals. It was more often ventral than dorsal, and lateral than median. In the female (Plate IV. Fig. 58), however, it extends directly through the middle of the mass of nearly ripe eggs.

The description of the structure of the alimentary canal already given for the male, holds good for the female as well, except that the lengths of the various parts are somewhat less than those of the male. The anterior chamber is much smaller, and the parts contained in it more compressed.

Bürger ('91, p. 643) described in general the four intestinal cells under the somewhat inappropriate name of œsophageal cells. He failed to recognize the cellular nature of the real œsophageal cell, since he speaks only of the tube and of a fibrous envelope. He seems to have entirely overlooked the loop in the tube, which probably existed in sections between those represented in his Figures 22 and 23, and naturally was able to give but little on histological structure. I do not believe it is advantageous to speak, as he does, of the intestinal cells as

cell-rows. There certainly are no transverse cell walls and no very regular distribution of nuclei; and while they may be potentially equivalent to rows of cells, they certainly are not the same as the structures in the Trichotrachelidæ known as cell-rows. To use the expression, then, is to emphasize a morphological relationship which, if it exist, is much more distant than the use of this word would lead one to suppose. Bürger also described the regions of the intestine bounded successively by four, three, and two cells; but in spite of his strongly expressed doubts on the subject, he was led to regard the terminal orifice of the papilla as the anus, following the description of Verrill and Fewkes. It must have been poorly preserved material which gave the appearances shown in his Figures 25 and 29, for I am convinced that the supposed cuticular lining of the intestine does not exist. I have found nothing which supports his claim, set forth at length, that the intestinal lumen when apparently bounded by three cells is really formed at the expense of only one, and belongs to that cell alone.

3. Anterior Chamber.

The anterior chamber is a prominent and characteristic feature of the anatomy of Nectonema. Even in the living animal one can usually distinguish its main features (Fig. 3) under a compressor. The semi-transparent area extends as far as the transverse partition which, at about 0.3 to 0.4 mm. from the apex of the head, cuts off this portion from the general body cavity. In the living animal this partition is concave anteriorly, and apparently slightly thicker at the centre; on sections it is seen to be covered on its anterior face by a thin peritoneal membrane, whose flattened nuclei (Plate VII. Fig. 95) may be easily discerned at intervals. I am not sure that this same peritoneal membrane lines the entire anterior chamber. It can easily be demonstrated over the lateral surfaces and around the œsophageal cell, where similar nuclei may be demonstrated even under the dorsal commissure of the brain and farther forward. On the dorsal surface of the brain I have searched in vain for the nuclei or the membrane; yet it is equally impossible to find where it stops, if it does not line the entire chamber.

In alcoholic specimens much of the regular character of the partition is lost, and it is usually found to be more or less distorted, as the effect of the various processes through which the material has passed. The fibres of which it is composed run in all directions, chiefly radiating from the centre toward the body wall. They show frequent pale nuclei (Fig. 95). The partition is pierced by the œsophagus alone, and it

encloses the œsophageal cell, so that no space is left on any side. The dorsal line does not extend as far forward as the partition, but the ventral line, which takes its origin from the brain, passes under the partition, the fibres of which spread out above it.

The anterior wall of the chamber is grooved externally, and this median groove, already mentioned, is supplied with one, or often two, low papillar elevations on each side. The cuticula on the anterior face of the head has about twice the thickness of that over the body in general. The underlying hypodermis from the mouth opening upward over the anterior dorsal aspect of the head is composed of high narrow cells, which are continued basally into one or more processes that are probably connected with nerve fibres. These relations are represented in Figure 92 (Plate VII.), which shows a somewhat oblique section near the apex of the head. It is the dorsal and lateral cells that are in question, and they show in some places very clearly the basal processes. Two such cells more highly enlarged are shown in Figure 93. The fibrous masses on either side into which the processes pass are the anterior prolongations of the fibrous mass of the brain. Bürger ('91, p. 637) has described these cells as rounded at the deep end, and he did not find their connection with the nervous system.

Along this part of the head and farther ventrad on the anterior face minute pore canals in the cuticula are by no means uncommon, and once or twice in total preparations fine hairs were seen in this region. Without having demonstrated any connection between the canals and hairs, I believe they are really united, and that the mass of cells which is here connected with the brain is sensory in function. Just dorsad to the mouth opening there was found in three specimens a small perfectly regular cuticular pocket about 30 μ in diameter. Its nature and value could not be determined, but, if at all significant, it is probably the remnant of a larval organ.

The striking transparency of this region in the living animal is due to the thinness of its walls. Everywhere but at the extreme anterior end the cuticula is thin, and, although the muscular layer begins in this region, it is insignificant. Only on the ventral surface does one find a mass of tissue, the brain with its capsule. The dark streak which in the living animal crosses the anterior chamber just in and above this mass is the œsophagus already described. The chamber is filled with a fluid in which float small scattered corpuscles of great transparency. Two such are shown in Figure 95, immediately below the ganglionic cell, *cl. gn.* V.

The most prominent objects in the anterior chamber, however, are the four big cells which, in two pairs, an anterior and a posterior, fill almost the entire space above the brain, and send their processes ventrad into its substance. They are the cells which Fewkes ('85, Expl. of Plates, p. 208) designates as "ova (?)," and which Bürger ('91, p. 646) supposed to be salivary glands. Neither hypothesis has much in its favor, and I shall present evidence which I believe shows them to be clearly nervous, i. e. ganglion cells. Accordingly, the description of their structure and relations will be deferred until the consideration of the ganglion cells in the brain.

4. Body Cavity.

The main body cavity extends from the posterior face of the partition which cuts off the anterior chamber to the extreme posterior end of the body. It varies much in size in different individuals (Plate II. Figs. 23–26, Plate IV. Fig. 58, and Plate VIII. Fig. 96) and can hardly be said to have a definite form. It is smallest in immature individuals, and most capacious after sexual maturity. It differs somewhat from the body cavity of the anterior chamber. The latter, as has been shown already, is lined, in great part at least, by a peritoneal membrane, but the general body cavity shows no trace of such a lining. The protoplasmic ends of the muscle cells terminate at variable depths, thus giving it an irregular boundary, which shows no sign of an endothelium. In the body cavity one finds neither dissepiments nor mesenteries; the intestine floats free, or at regular intervals in its course is grown fast to cells in some part of the body wall.

In the male one always finds a sac more or less developed hanging from the dorsal line, and varying in form and structure. This will be more fully described under the sexual organs, to which it unquestionably belongs.

There is often a small amount of coagulated substance in the body cavity which contains scattered corpuscles similar to those of the anterior chamber. They are very pale, entirely unstained, and of a spongy texture. One finds various sizes, and their origin from the protoplasmic ends of the muscle cells has already been maintained. They are by no means abundant, and the amount of coagulum found in the body cavity is also small. In addition to these one always finds in the body cavity of the male free spermatozoa in greater or less numbers. In all of the females obtained the body cavity was nearly or quite filled with eggs.

5. Nervous System.

a. Brain.

The anterior ganglionic mass, or brain, forms the larger portion of the floor of the anterior chamber (Plate V. Fig. 63). In general it is somewhat wider than long, being from 0.16 to 0.28 mm. in width, and from 0.12 to 0.2 mm. in length, and has an average thickness of only 0.14 mm. (Figs. 3, 8, 63, 72–88). Its anterior limit is the one most difficult to make out, since the brain substance goes over gradually into the tissue in front of it, from which it is not separated by any prominent capsule. The middle of the dorsal surface is marked by a longitudinal groove, in which the œsophagus lies. Behind the narrow meagre cerebral commissure the œsophagus is separated from the brain by a considerable space, and here the dorsal groove in the latter is wider and less defined than farther forward. (Cf. Plate VI. Figs. 72–88.) Laterally the limits of the ganglionic mass are more distinct, although no envelope of connective tissue separates it plainly from the adjacent cells. In fact, there does not seem to be a definite capsule anywhere, even on the dorsal surface. In places the limits of the mass are so sharp as to suggest a covering membrane, but I was unable to find any corresponding nuclei. The connective-tissue fibres which bound the ventral nerve cord dorsally are first apparent behind the last pair of large ganglion cells of the brain.

α. Ganglion Cells. — On the whole the brain is poorly supplied with ganglion cells; of those found, one can nevertheless distinguish two kinds, which represent extremes in size. The first and smaller kind is only moderately abundant, but they far exceed in number the second. No appreciable amount of cell protoplasm can be seen about them, but they appear everywhere simply as small oval nuclei (Plate V. Fig. 68) only 4–5 μ in diameter. These nuclei stain deeply, and show a thick nuclear membrane with numerous chromatic granules, of which one, or occasionally two, are very prominent. In general they correspond closely to the nervous nuclei (Nervenkerne) described by various observers for different groups of animals. A further point of resemblance is found in their position, for they lie embedded in a mass of fibres, and, although it is difficult to decide whether certain of the fibres are connected with them, appearances decidedly favor this view. Cells of this kind are most abundant on the anterior face of the ganglionic mass, and around the stalks of the dorsal cells. In the fibrous mass of the brain they occur ordinarily only at the ventral surface, and in one or

two definite lines whose significance will be considered later. (Cf. Plate VI. Figs. 72–88.)

The large ganglion cells so far surpass in size those of the first kind that they might well be called giant cells were it not that the name implies a homology which I do not wish to affirm. There are in all five pairs of these large cells, which are nearly constant both in position and in size. Figure 94 (Plate VIII.) represents them diagrammatically and from a comparison of this with Figure 63 (Plate V.) the different cells may be recognized at once. It will be convenient in the description to designate them by numerals, beginning with the most anterior pair.

Since the chief characteristic of the cells of the second class taken as a whole is the nucleus, I shall begin with a description of this structure, which is relatively very large and somewhat irregular in form (Plate V. Fig. 69). It never stains deeply, and shows one or more clear vacuolated areas. The nuclear membrane is delicate, and the chromatic substance finely distributed in lines or rows of dots. The nucleoli vary; sometimes (Pl. VII. Fig. 95, *cl. gn.* III.) none are present, and again there are (Fig. 95, *cl. gn.* V.) one or two very prominent ones, or in other cases (Pl. V. Fig. 69) a number of smaller ones. Frequently, one finds within the nucleus structures (Fig. 69) of an irregular appearance surrounded by a clear space of varying width, and bounded externally from the surrounding nuclear matter by a very definite line. It appears as if the irregular bodies had originally filled the clear space or vacuole, and had shrunken away from the enveloping nuclear matter in the process of preservation. Exactly similar structures occur in the nuclei of the dorsal cells to be described, as well as in the nuclei of the large cells in the anal ganglion: whatever the nature of these enclosures may be, they seem to be characteristic at least of the larger ganglion cells. I do not know that similar bodies have been found in ganglionic cells of other animals.

The amount of protoplasm which surrounds the nucleus in the five pairs of large ganglion cells varies, somewhat in relation to the position occupied by the cells. The cells of the most posterior pair (Fig. 95, *cl. gn.* V.), which protrude above the mass of the brain, have a considerable amount of cell protoplasm; those of the third pair (Fig. 95, *cl. gn.* III.), which are only partly surrounded by fibres, show a lesser quantity, while the others, which are deeply embedded in the fibrous substance, have merely a thin mantle of protoplasm surrounding the nucleus.

Although numerous fine processes pass off from the cell body in various directions, each cell has one prominent process, which may usually be followed without difficulty. They are, hence, really unipolar cells. Of these cells the first and fifth pairs (Fig. 94) are much larger than the others, the third is intermediate in size, and the second and fourth are considerably smaller, though nearly equal in size to each other. All things considered, each of these cells has such a characteristic appearance that after study it is possible to recognize at once a cell from any pair.

One also finds a few cells about half as large as those of the second class; they vary in position and seemingly in number in different specimens. A pair of these are shown in Figure 84 (Plate VI.) between the nuclei of the fifth pair of large cells. These cells are too indefinite in number and position to be regarded as constituting a third class. They resemble the cells of the second class in general appearance, differing from the latter only in size. At most one finds two pairs of such cells ventral to the fourth pair (Fig. 84), and another pair anterior to the third pair of large ganglion cells (Fig. 76). They constitute perhaps an appendix to the cells of the second class.

It is necessary now to ascertain the exact position and relation of these cells to other parts of the nervous system. Figures 72 to 88 (Plate VI.) represent a series of successive transverse sections including the entire brain. By comparing them with Figures 63 and 94, one may determine the exact position of the large cells, and follow their processes. In the cross sections only the nuclei are represented, since the cell body is too small and too poorly marked off from the surrounding tissue to be seen under this power.

The first pair (Plate V. Fig. 63, *cl. gn.* I.) lie farthest anterior, as well as most ventral of all. They usually approach the median plane of the body very closely, being separated from each other by only a narrow space. Occasionally one of them lies a little higher than the other in the fibrous mass of the brain. These cells are pear-shaped (Plate VII. Fig. 94), with the long diameter parallel with the chief axis of the animal. Each possesses a single large process, which passes directly backward. As the two processes from these cells pass posteriad they approach each other and rise slightly, by which they come to lie in the central V-shaped portion of the ventral nerve cord (Plate VI. Fig. 88).

The second of the five pairs of large cells is somewhat smaller than the first, and its position varies within narrow limits (Plate VII. Fig. 94).

In Figure 75 (Plate VI.) the left cell of this pair is represented; the corresponding right cell has fallen out or is aborted in this series. The general position of these cells may be said to be midway between the first and third pairs, as well in height as in antero-posterior relation. They may in some cases lie nearer the median plane than the following pair, as well as farther from it in other cases. The extremes of variation in both directions are shown in Figure 94 (compare the right with the left). It was very difficult to follow the processes of this (second) pair, and I can only say I think they pass into the dorsal commissure, and through that to the opposite side of the body; but their further course could not be made out. It is close to this pair of cells that the stalks of the anterior dorsal cells enter the brain. (Compare Figure 94, *pd. cl. d.*, the anterior of the two stalks.)

The third pair of large cells may properly be called the commissural cells, on account of their intimate connection with the dorsal commissure. They are pear-shaped cells, and lie on the extreme upper surface of the brain, and near the median plane, as may be seen in cross sections (Fig. 77). Their position with reference to the commissure is somewhat variable. Sometimes they are located well to one side in the brain mass (left side, Fig. 78), but again they are found well up on the commissure, even so far that the apex of the cell reaches the median plane, and the entire cell is dorsal to the œsophagus (Plate VIII. Fig. 99, *cl. coms.*). As has already been intimated, the processes of these cells cross through the commissure to the opposite side of the body. After leaving the commissure, they bend at once sharply to the rear, and may be followed some distance. They were ultimately lost to view near or alongside of the fifth pair; not because they are in any way connected with those cells, but rather because the size of the latter tends to obscure the neighboring processes. I believe that the processes pass one into each lateral bundle of the ventral nerve cord, but this point could not be established with absolute certainty.

The fourth pair of cells (Figs. 63 and 94, *cl. gn.* IV.) makes its appearance several sections back of the third. They are intermediate in size between those already described, and possess nearly spherical nuclei (Plate VI. Fig. 82, *nl. gn.* IV.). They occupy the dorsal portion of the ganglionic mass near its posterior end (Fig. 63), and are situated only a short distance from the median plane. Their processes pass sharply ventrad and toward the median plane, where they ultimately come to lie near the processes of the first pair of cells in the central unpaired portion of the ventral nerve cord. In spite of the difference in size between

the first and fourth pairs of cells, their processes cannot be distinguished from each other in size (*pr'c. gn.*, Fig. 88).

The fifth pair of cells lies farthest lateral and dorsal of all (Plate V. Fig. 63), forming as it were the posterior outer corners of the ganglionic mass. They are the largest of the five pairs of cells, on account of the larger amount of protoplasm which surrounds their nuclei, and they lie wholly without the fibrous mass of the ganglion (Fig. 63); in fact, they often project above the general level of the brain (Plate VI. Fig. 85). The processes of these cells are the most prominent of all, having a diameter twice as great as those from any other pair of cells. They pass directly backward into the corresponding lateral bundle of the ventral nerve cord, and for a long distance occupy the centre of this portion; but farther back they cannot be distinguished among the numerous processes which occupy this portion of the cord.

β. Dorsal Cells. — The probable nervous nature of the dorsal cells has already been referred to, and to make this clear it is necessary to consider in detail their structure and relations to the brain. In life they appear spherical when viewed from above (Fig. 2), but when seen from the side (Fig. 3) they are evidently conical. The two constituting the anterior pair lie in juxtaposition at the median plane, the posterior ones farther apart and in contact with the posterior and lateral portions of the first. No particular structure can be made out in the living cell further than the presence near the stalk of a dark body, presumably the nucleus. The stalks pass ventrad and slightly posteriad into the substance of the brain, where they are seen to bend decidedly backwards (Fig. 3), and are then lost to view. Nothing further was determined from the living animal, since the possibility that they might be nerve cells did not force itself upon me until much later.

In preserved specimens the shape of the cells is much altered. They are usually shrivelled and distorted; or, again, they often contain a huge vacuole on one side (Plate VIII. Fig. 98). Unstained specimens cleared in clove oil serve only to confirm what is seen in the living animal, and show quite distinctly that the stalks of the cells are not connected either with the œsophagus or the external cuticula at any point. There is also clearly apparent in the cell a fine network, which takes its origin from the stalk (compare Fig. 99), and fills the whole cell with a mass of minute meshes. If now we examine sections through this region, the peculiar character of the cells becomes more apparent (Fig. 99). Each is surrounded by an extremely fine membrane, which is continued on to the stalk as a delicate superficial layer hardly recog-

nizable. The dorsal end of the stalk projects a perceptible distance (Figs. 99 and 67) within the membrane into the cell, and seems to be resolved into a number of fine branches, which make their way in all directions through the cell, and give off still finer processes, which anastomose to form a network of finest fibrils. These are highly refractive, and, like the stalk, take up staining fluids slightly, so that the coarser branches assume a decided tint in well stained specimens.

Near the stalk in the lower portion of the cell lies a stainable body, the nucleus (Plate VI. Fig. 78, *nl. d.*) ; this is of such a peculiar character as to make its right to the name nucleus appear at first sight questionable. It is irregular in form, and often has a very indistinct contour (Plate V. Figs. 64, 65), since a nuclear membrane can be seen only in places. The larger branches of the network already described connect directly with the projecting angles of the nucleus, so that the latter often seems to be prolonged some distance out into the cell. In the ground substance of the nucleus, when lightly stained, one sees a network similar to that already described as existing in the cell plasma, and with which it seems to be connected. There are, besides the network, at least two distinct sorts of enclosures in the nucleus : first, comparatively regular bodies (Fig. 64, *nll.*), nearly spherical in shape and about 5 μ in diameter, which are uniformly and deeply stained, and which in every respect resemble nucleoli ; secondly, irregular bodies (Fig. 64, x), which are always surrounded by a lighter area of varying width, and which thus have the appearance of being shrunken. These do not stain either like the first-mentioned bodies or like the rest of the nucleus itself, but in depth of color are half-way between the two. What these enclosures may be I do not know, but I believe the larger mass itself to be the nucleus, despite its peculiarities, and I regard the dark round bodies enclosed within it as nucleoli. It may be urged in this connection, that the very irregular form of the nucleus makes it impossible to cut the surface perpendicularly for more than a short distance, and that an oblique cut would make the membrane very indistinct. This probably accounts for its apparent absence in places.

It is possible, I think, to furnish at least a partial explanation of these peculiarities. Evidently the cells contain a highly fluid plasma. This is shown by the small quantity of solid matter found in those that have been "fixed," and by their variation in size. This condition might indeed be expected on purely physical grounds, since the cells float entirely free in the fluid which fills the anterior chamber. If however cell and nucleus contain more fluid than ordinarily, the curious appear-

ance, especially of the latter, can be easily understood : the nucleus has been shrunk by dehydration in the course of preservation. This shrinkage was prevented in a measure at certain points where the strong threads of the network were connected with it. It is important in this connection to call attention to the fact, that in those cases where the cells were unusually small the nucleus was most nearly regular in shape (Fig. 66). No particular attention was paid to this point when studying the living animal, but in the sketches made at the time I find that the nucleus, which in general size and position agrees with this structure, was drawn with a regular oval outline (Fig. 2). This may well be its shape in life.

The stalks of these four cells present a uniform appearance. They, or at least their initial portions, stain more deeply than any other tissue both in hæmatoxylin and in carmine solutions, and hence are easily traced so far as the stained portion extends. Under a high power the stalk exhibits in places a faint longitudinal striation, and sometimes shows lines of minute vacuoles between the striations. The method of termination in the cell has already been described. From the cells the stalks pass directly into the brain, those of the first pair entering just lateral to the second large ganglion cell on either side, and those of the second pair just antero-lateral to the fifth pair of large ganglion cells in the brain (Plate V. Fig. 63, *pd. cl. d.*). The processes, which in transverse sections appear to be directed toward the median plane, show in longitudinal section (Plate VII. Fig. 95, *pd. cl. d.*) a backward tendency also. They may in this way be followed for a very few sections ; in the last, in which they are prominent, one sees a splitting or branching of the process in various directions, but beyond this the parts can be traced at most a couple of sections. The more compact character of the mass and the large number of other fibres make it difficult to say whether any part of the process extends farther, or whether the whole is split up at this point into fine fibrillæ. The place where the splitting begins is surrounded by a considerable number of small ganglionic cells (Plate VI. Figs. 78, 82).

Bürger ('91, p. 639) describes two pairs of large ganglion cells and two subordinate pairs in the brain. His description is not in all points clear, and to judge from appearances the figures do not correspond to his interpretation. Of the structures which he calls "giant cells," the anterior pair is my third or commissural pair ; his posterior pair corresponds to my fifth pair. Of his subordinate cells, the pair which lies close to the commissure corresponds perhaps to my second pair, and

those described as lying between the two pairs of giant cells are my fourth pair. His figures do not fully agree with this, however. His Figure 2, *Gz*, shows the "anterior giant cells," which are clearly my commissural cells; Figure 11, *Gz*, which he regards as one of the same pair, has more of the appearance and position of a cell of the fifth pair. The dorsal cells are described as salivary glands (*Spdz*, Figs. 1, 2, 11), and it is curious that he has nowhere represented the prominent processes (stalks) of these cells, unless, indeed, they are the structures labelled *Gz F* (Fig. 12). Although the position is somewhat peculiar, they certainly look more like the stalks of the dorsal cells than like processes of the cells marked *Gz* in the same figure, which is his interpretation, since the latter usually extend directly backward.

Bürger expresses a doubt that the posterior giant cells (i. e. my fifth pair) lie opposite each other. If not, it was because of some deformity or twisting of the head, as they evidently are opposite each other in my preparations (Figs. 63, 85). Instead of being nearer together than the other cells, as he maintains (p. 640), they are certainly farther apart than the components of any other pair (see my Figs. 63, 85).

γ. *Fibrous Mass.* — The central fibrous portion of the brain shows few definite points of structure. The fibres run in every direction; one finds few commissural bands, and in general no fixed arrangement. At two points, however, one notices (Fig. 99) vertical bands of fibres which divide the brain into three parts, a central and two lateral portions, which in position correspond to the three divisions of the ventral nerve cord, which will be described later. The dorsal commissure (Plate VI. Fig. 80, *coms. æ.*) is very meagre, being cut in only two or three sections. The number of fibres in it is consequently small, but there are at least four large nerve processes; two belong to the third or commissural pair of cells, the other two perhaps to the second pair. A few finer fibrils accompany these.

In the female the brain measures only 0.08 mm. in length, and 0.1 mm. in width. In consequence of its more compressed form, the cells stand closer together, and are more difficult to study. One finds exactly the same number of large ganglion cells, and they occupy corresponding locations. It may, then, be fairly assumed that the processes are distributed in the same manner, although I was unable to follow them as clearly as in the male.

In total preparations (Fig. 63) one often sees groups of fibres passing anteriad from the brain into the front wall of the anterior chamber. As has been shown from sections, however, this is all solid tissue in front of

the brain, and these groups of fibres are apparent merely by virtue of a different refractive power. They are somewhat irregularly arranged, and yet correspond very nearly on the two sides of the body. I regard them as groups of nerve fibres. They may be seen to turn dorsad (Plate VII. Fig. 92, *n. a.*) in the tissue of the wall, and probably innervate the numerous sensory cells found in this wall.

b. Ventral Nerve Cord.

The ventral nerve cord extends directly posteriad from the brain through the entire body. It is located in the ventral line just above the epithelial layer, and appears in cross sections near the middle of its length as a roughly cordiform mass (Plate VIII. Fig. 101), which is separated by internal divisions into three areas. These areas represent the three nerves of which the cord is composed. The median area (Plate VIII. Fig. 101, *n. m.*) is triangular, with its apex directed ventrad, and is, so to speak, wedged in between the two oval lateral areas. Near the brain the form of the ventral nerve cord is somewhat different, and gives a hint as to its relation to the brain, which can be easily traced in any series of sections which includes the brain and the following portion of the body. The first trace of a partition in the fibrous mass is found well forward in the brain, and is shown in the arrangement of the small nervous nuclei, and of the dorsoventral groups of nerve fibres already mentioned; these indicate a division of the brain into a central mass quadrangular in cross section, and two lateral masses more or less rounded off on the outer side (Plate VI. Fig. 86). At the position of the fourth pair of large cells a row of small cells, already mentioned, makes this division more apparent, and even before reaching the ventral nerve cord one sees the separation of the three portions by fibrous bands which cross the brain vertically. At the beginning of the nerve cord the three portions are of about equal size; gradually the lateral areas push themselves in under the central portion until the latter has been compressed into a triangular shape, with the lateral areas almost touching in the median plane beneath it. This relation, with slight modifications, is preserved throughout the entire length of the animal, and I do not find, as Bürger (p. 641) has maintained, that the median portion is more prominent in the anal ganglion (Plate VIII. Fig. 96, *n. m.*). The central and lateral portions seem to be, so far as I can find, alike in structure. The number of faintly stained homogeneous processes in the three portions is nearly equal; in the posterior part of the body they are perhaps more numer-

ous in the lateral portions of the cord. Each part also contains nerve fibrillæ, and the relation of the ganglion cells to each appears to be the same.

There are, moreover, ganglion cells in the ventral nerve cord; they may be conveniently treated of in two groups, which correspond in general to those of the brain. The first are simple nervous nuclei, distinguished from the nuclei of the surrounding connective tissue especially by the intensity with which they take up stains. They are small oval nuclei, measuring 4–5 μ by 6–8 μ in diameter, and possessing a prominent nuclear membrane, but not provided with any appreciable amount of surrounding protoplasm. They are found along the dividing lines between the areas of the cord (Plate VIII. Fig. 101) and also on the external boundary of the latter, usually closely crowded together; in cross sections they appear as a single or double row; in longitudinal sections they are collected into a certain area (Fig. 97). They are about equally distributed throughout the length of the cord, and produce the dark dotted rows seen on the ventral line in the living animal (Fig. 7).

The large cells of the ventral cord form the second class, and in many cases are equal in size to those of the brain. Though not plentiful, they are scattered along the whole length of the cord. I was unable to find, however, any regularity of distribution, since the interspaces vary considerably in extent. Furthermore, they are not plainly paired except in rare cases. Usually the successive cells are separated from one another by a distance equal to the thickness of ten, or even twenty, cross sections (100 to 200 μ). Bürger (p. 641) has described these cells under the name of median cells. I do not think that they begin, as he maintains, in the brain; but I agree with him in regarding them as unpaired. These big cells are ordinarily found wedged in between the two lateral areas and immediately below the ventral portion of the cord (Plate VIII. Fig. 101). So far as I have seen, these cells possess each but a single process, which passes dorsad between the median and one of the lateral areas, but its ultimate fate I was unable to determine. Rarely one finds a large cell below the lateral area on one side or the other. In this case the nucleus is much flattened dorsoventrally. Bürger regards these cells as bipolar. I have seen appearances such as he represents in his Figure 13, but do not regard this as decisive, since the two processes are not shown, so that, while I have no positive contradictory evidence, I am also unable to confirm his statement.

The form of the ventral nerve cord may be much altered by collapse of the body, which flattens the cord between the two lateral muscular

areas. By this process the elements of the ventral line, as well as those of the cord itself, are so changed as to give rise to abnormal appearances even in otherwise well preserved specimens. Such a crushed condition of the cord is figured by Bürger (Fig. 19).

Strictly speaking there are no nerves arising from the cord. The fibres which branch from it are nowhere collected into a group worthy the name of nerve. In every second or third section one finds a few delicate fibrils arising from the nerve cord; some emerge from the dorsal surface and some from the median ventral cleft, and in both cases they pass off towards the lateral hypodermis (Fig. 101). They may be traced as far as the beginning of the hypodermis proper, but their ultimate fate is unknown. If these are not nerve fibres, I am at a loss to explain them, or to find other branches which may be nervous. Only once did I find any evidence of a large process leaving the cord; in one cross section a process like those found cut transversely in the cord was cut longitudinally; it passed out from above the lateral area and followed the course of the fibres already described, as far as the hypodermis.

c. Anal Ganglion.

Bürger has shown (p. 638) that the anal ganglion far exceeds the brain in size, and is in no sense a small local thickening of the ventral nerve cord, but that it is a gradual differentiation of its posterior portion. In a total view (Plate VI. Fig. 89) one is unable to see any definite line of demarcation between the ventral nerve cord and the ganglionic enlargement which terminates it. There is seen to be rather a gradual increase in the size of the cord extending over a distance of about 1.2 mm., and culminating at the posterior end, where the ganglion is abruptly rounded off. In some specimens the differentiated portion of the cord is deeply cut by cross furrows which give it a metameric appearance. Although these may be present at times when no external folding of the cuticula can be found (Bürger, '91, p. 638), they certainly do not indicate any metameric condition of this organ, since they vary in size and since there is no corresponding structure in them. The furrows are entirely wanting in most well preserved specimens (Fig. 9), and when present are simply due to a folding of the cord, such as occurs in other portions of its length as well, but is more prominent here on account of the thickness of the organ.

A cross section through the anal ganglion (Plate VIII. Fig. 96) shows at once that the increase in size is due chiefly to the addition of a peripheral layer of cells above the cord proper. On account of this increase

in size it is no longer possible for the ventral line with the entire nervous mass to be retained in its usual position. It is therefore forced upward into the body cavity, and fills a considerable portion of it (Fig. 9). In fact, near the end its diameter is half as large as that of the body at that point.

Seen in cross section (Fig. 96) the nerve cord itself presents little here that is different from its general character throughout the body. It is the peripheral layer which demands particular attention. This is crescent-shaped, and composed of a dense matrix in which are embedded many nuclei. Along its periphery the matrix is finely striated perpendicularly to the surface, and is separated from the underlying nerve cord by a narrow space filled with loose fibrous tissue (Fig. 97). The horns of the crescent are turned ventrad around the nerve cord, and are connected with the tissue lying below it. In these horns one sees a fine longitudinal striation; occasionally more plainly marked fibres, coming from the cells above, may be traced into them. The matrix, which usually takes a faint stain, contains numerous oval nuclei (Plate V. Fig. 71) with a sharply defined nuclear membrane. The nucleus in general does not take up the stain, so that the one or two large nucleoli stand out in strong contrast to the rest. One can neither find any cell boundaries in the matrix, nor determine how much, if any, of the surrounding protoplasm belongs to each nucleus. In fact, the fibres which one finds often appear to extend from the nucleus itself around into the horn of the crescent.

In addition to this thick peripheral layer, which I regard as nervous, there are in the anal ganglion a few large cells. Some are wedged in below the middle portion of the cord like those which have already been described. Others may be found in the space between the peripheral layer and the cord (Fig. 96), with the process directed ventrad. These cells do not as a rule appear to be paired.

At the extreme posterior end of the cord one finds somewhat different conditions. Here there is a mass of large ganglionic cells of varied size, closely crowded together, and with their processes (Plate VII. Fig. 90) mostly directed forward into the ventral nerve cord. The space between the cord and the peripheral layer does not exist, and, curiously, the ganglion cells of the latter have nearly always two nucleoli instead of one as is usual elsewhere. The relation of the cells and processes is very complicated here, and the gradations of size are so fine that with the material at my command I was unable to determine the exact number of cells, or the plan on which they are arranged. The nuclei of these

cells recall those of the brain. One finds (Plate V. Fig. 70) the same distribution of chromatic substance, but with more numerous nucleoli, and the same sort of enclosed bodies. One edge of the nucleus shown in the figure is very indistinct, because it was cut obliquely. It recalls the appearance presented by the nucleus of the dorsal cells. The same is true of the nuclei of the large ganglion cells in the ventral nerve cord seen in longitudinal section.

The female does not show any such extreme modification of the posterior end of the ventral nerve cord as was found in the anal ganglion of the male. The only specimen favorable for the study of these relations shows (Plate IV. Fig. 57) a slight swelling in the ventral nerve cord just at its end, which lies below the terminal bulb. There appear to be a very few large ganglion cells at this point, and yet it is an unimportant modification as compared with that of the male. The peripheral layer of ganglion cells, so characteristic of the anal ganglion in the male, seems to be entirely lacking in the female.

6. Sexual Organs.

a. Male.

In all males one finds a sac suspended from the dorsal line and filling a larger or smaller portion of the body cavity. It shows the character of its walls best when almost empty. Then one sees a fine outer boundary (Plate IV. Fig. 54), with occasional elongated deeply stained nuclei. From this fibres radiate through the cavity of the sac to form a delicate large-meshed network, or the sac may in places be entirely empty. These details are all hidden when the organ is filled; even the walls cannot be demonstrated, although their presence may be inferred from the regular outline of the mass. In this case the sac is enlarged so as to fill a considerable portion of the body cavity. This is true of the anterior or middle region of the body; farther posteriad the sack seems to become crescentic in cross section, the two horns of the crescent being fastened to the lateral body walls. When the sac here is filled, it occupies the entire space dorsal to the anal ganglion (Plate VII. Fig. 90).

In most cases the sac is filled with minute oval bodies of uniform size, only 1 μ in diameter. No other structures are constantly present, so that their abundance, minuteness, and uniformity in size and appearance render it practically certain that they are spermatozoa, and that the sac is the male generative organ.

In some specimens cross sections through the middle or anterior region of the body show that the sac is moderately filled with cells whose nuclei stand close together and are in a kinetic condition. Here the ventral boundary of the dorsal line seems to be wanting in places, as if the cells in the sac were directly connected with those of the dorsal line, while the wall of the sac is laterally directly continuous with the basement membrane, which covers the line ventrally. One can sometimes find among the cells in this region stages which seem to show a transition between the kinetic nuclei and the groups of spermatozoa found among them; but this condition was encountered in only a single specimen, and the material was not in sufficiently perfect histological condition to allow a study of spermatogenesis. This anterior portion of the sac I regard therefore as testis, and the posterior crescent-shaped portion as at once receptaculum and vas deferens. In the stage in which the kinetic nuclei were found in the anterior portion of the sac, the walls of the posterior portion were collapsed, and hardly a single spermatic element was to be found in it. This is the youngest stage which I have studied.

In another, older stage the sac was filled from end to end with the deeply stained highly refractive spermatozoa, and so enlarged that it occupied nearly the entire body cavity. Finally, in the oldest stage found the sac (Fig. 11) appears in the anterior part of the body as a mere remnant with collapsed walls containing an occasional spermatozoön. At the tail, however, a small quantity of spermatozoa was collected near the terminal orifice. The diminished thickness of the protoplasmic zone in the body wall shows this individual to have been comparatively old. In one specimen in which the sac was thus collapsed, however, the body wall was moderately thick. In these cases copulation seems to have taken place, and the few spermatozoa are merely remnants of the original contents of the sac.

The organ described by Bürger on pages 646, 647, is evidently the same as this, and his belief that it was a testis rather than an ovary is confirmed by the preceding account. The description he gives of the organ either shows that the specimen studied by him was intermediate between the first and second stages here described, or else was based upon different individuals and represents different stages.

In one of my individuals which, to judge from the thickness of the body wall, must have been young, there were clusters of polyhedral cells here and there in the anterior portion of the body cavity, and these clusters were crowded full of spermatozoa in small bunches, as if they

had originated there. The dorsal sac was moderately large, and contained numerous spermatozoa, which were, however, scattered, and not in groups. I do not know how to explain this case, unless indeed it be due to a rupture of the dorsal sac in places, and the consequent evacuation into the body cavity of a part of its contents. Although I did not find any point at which this could be shown to be unmistakably true, yet there were many places where the wall could not be distinguished; furthermore the body was in this case much distorted in killing. Even when the outlines of the sac are plainest, one always finds spermatozoa in the body cavity in greater or less numbers; so, for example, in the cavity of the terminal organ (Plate IV. Fig. 53). This, so far as I know, is the only fact which favors the view that their place of origin is in the body cavity; aside from this, the evidence points to the dorsal sac as testis. A further study of additional material is necessary to determine finally this point, as well as many others.

The external sexual organ of the male consists of the terminal papilla to which reference has often been made. It has much the shape of a slightly curved truncated cone (Fig. 53) with an opening at the smaller base, and with the larger base joined to the body obliquely, so that it naturally turns ventrad. The length and curvature of the organ vary a little, as can be seen from the different figures (Figs. 4, 9, 53, 89, 90). The essential features of its structure can be made out from a total preparation in clove oil (Fig. 53). The muscular layer of the body wall, which for some distance has been growing thinner, stops suddenly along a well defined line. Beyond this only the hypodermis lies between the cuticula and the body cavity. The cuticula, which is here a little thicker than usual (see also Plate VII. Fig. 90) is infolded at the end of the organ and runs forward as the lining of the cavity for a variable distance. I was at first inclined to believe that this infolded portion could be to a limited extent extruded and then drawn in; but further study seems to show that it cannot. The thick cuticula is too stiff to be rolled in or out without being folded somewhere, yet on sections it is always smooth; moreover, there is no muscular provision for moving the organ in this way. At its anterior end the cuticular infolding is continous with a sac (*va. df.*) having delicate walls, and this is in turn connected with the dorsal sac previously described (Fig. 53 and Plate VI. Fig. 89, *va. df.*). Although I plainly saw and drew in several cases the walls of this connecting portion from clove oil preparations, yet they are so delicate that in sections they were not once preserved except as loose shreds of tissue. I was consequently unable to ascertain whether there was

anywhere the trace of a connection with the intestine. On general grounds one would be inclined to believe that the single terminal opening was that of a cloaca; but no evidence of any connection between the end of the intestine and this thin-walled portion communicating with the dorsal sac was obtained. It must then remain for future investigations to decide whether this is morphologically a cloaca or merely a vas deferens.

The hypodermis in the terminal papilla is composed of a single layer of approximately cubical cells (Plate VII. Fig. 90). This is the only portion of the body wall in which the boundaries of the hypodermal cells can be seen.

The spermatozoa are usually found in such enormous numbers that it is difficult to make out their true shape. They appear much like micrococci, and when seen alone (Plate IV. Fig. 55) are slightly oval, highly refractive bodies 1 μ in diameter. The merest indication of a protoplasmic envelope surrounding them is found in the shape of a very narrow light peripheral zone. They stain very deeply, and their minute size renders it impossible to recognize any structure in them. It is probable that, as in other Nematodes, the spermatozoa undergo some metamorphosis after being introduced into the body of the female. From one individual spermatic masses were voided into the sea-water in which it was kept. There was no sign of motion in the mass when flattened under a cover glass, and when dried on a cover glass and stained nothing besides the oval spermatozoa could be seen, except a certain amount of coagulated fluid.

There may be found in the dorsal sac as well as in the body cavity of certain male specimens peculiar pale bodies, not easily stainable and varying greatly in form. They are probably the same as those which Bürger (p. 647) speaks of as "ovale Gebilde von mattem Glanze, an denen nicht zu errathen war, ob sie gleichfalls Kerne oder Einlagerungen bedeuten." Macerations show that they are probably parasitic Gregarinida, the various appearances obtained from sections being due to their having been cut in different planes (Plate VII. Fig. 91).

b. Female.

I do not believe that any of the previous observers have had a female. Verrill ('79) described the posterior end in the "female" as "subtruncate with a small terminal papilla." This applies exactly to some males, and, as Figure 56 (Plate IV.) shows, is very unlike the

female.[1] Furthermore, in the entire collection which Professor Verrill kindly placed at my disposal there was only one female, that one being found coiled up in a mass of twenty specimens.

Bürger (p. 647) describes one form which differs materially in structure from all others studied by him; he was inclined to regard it as a female. He found a sac with flattened walls hanging from the dorsal line. The description and figures given by him resemble strongly an immature testis, — certainly it cannot be an *empty* ovary. But the termination which he describes for it is so extraordinary that one must doubt the normal nature of the specimen or the accuracy of the observations. Certainly neither in male nor female does one find anything like the tube and cells which he describes as lying on the ventral cord, except the œsophagus. It is impossible, however, that he has mistaken the anterior for the posterior end of the worm, because he mentions the head of this specimen. There are certain points in his description of this individual, especially the lack of an anal ganglion, which recall the female, yet in view of the many problematic points which cannot be referred to either sex, I am of the opinion that this must have been a very abnormal specimen. I shall give a description of the sexual organs of the female without any further reference to his work, describing only those conditions which I believe to be normal.

The three females obtained present three stages in the growth of the egg, but unfortunately all are too far advanced to give any clue as to the place or method of origin of the egg cells. In the first stage the body cavity is already half filled with well developed eggs, and no trace of ovaries or of the walls confining the ova is present, but the ova seem to lie free in the body cavity. Each egg (Plate IV. Fig. 60) has a firm outer membrane, highly granular protoplasmic contents, and a large irregular nucleus, which has a very thin nuclear membrane and is strikingly poor in chromatic substance. Between and around the eggs one finds a granular substance, and more rarely small nuclei.

In the next older stage the body cavity is more nearly filled, and the eggs are very similar except that the nucleus is smaller and more deeply stained. One finds also around each egg an external covering of minute quadratic blocks, which seem to be easily separable from the egg and from one another.

The oldest stage observed differs from that just described in some

[1] I should not neglect to mention that a female with protruding egg mass (see Fig. 10) would correspond generally to this description; but such a state would hardly be available for identification.

small particulars. The nucleus (Fig. 61) is now so small as to be found with difficulty among the large opaque yolk granules, the external membrane is firmer, and the blocks with which it is covered are more prominent. In this stage the eggs fill the entire body cavity (Fig. 58), being roughly arranged in nearly concentric layers. It was from this individual that eggs were discharged into the water and later preserved. At first sight (Fig. 62) such discharged eggs appear very different from those previously described, being armed with a thick covering of long conical spines. An examination of the posterior end of this animal, which was killed while the eggs were being discharged, showed that the eggs which were still in the body and those in the mass outside possessed not a trace of these spines, but simply the blocks on the external membrane, as already described. Further investigation showed that *not all* the eggs which had been laid were already provided with long spines. In some cases the spines were very short and thick; indeed, all stages were found from this condition up to the one first described. The probable explanation of this phenomenon is, that the block-like thickenings on the membrane of the immature egg are swollen by the sea-water, first into shorter, then into longer spines, which at the beginning are probably soft and become rigid later. Certainly in alcoholic specimens they are rigid.

In almost every transverse section one finds a delicate membrane stretching from the ventral line to the egg mass (Fig. 58). This may represent a mesentery, as it is too uniform to be merely accidental. In only one case (Fig. 57) was there anything present in the body of the female which had the appearance of spermatic elements, but the poor histological condition of this specimen prevented an accurate determination of the matter.

The body of the female ends (Fig. 10, and Plate IV. Figs. 56, 57), as already mentioned, in a slight bulbous enlargement with a central terminal opening. The cuticula turns inward for a short distance, as in the male, but in the specimens at my command there were no internal organs connecting with this opening. The mass of eggs filled the body cavity up to the tissue of the terminal bulb. The same question recurs here which suggested itself in the case of the male, as to the morphological value of this opening, — whether it is or is not a cloacal orifice; but I have no evidence to present on either side of the question. The bulb is made up of elongated cells containing pale nuclei, and passing off at right angles to the infolded cuticula. These cells have much the appearance of unstriped muscle cells, and seem to be able to affect the

caliber of the opening (Figs. 10, 56), and thus to facilitate the passage of the egg mass. The hypodermis can hardly be followed around the bend under the infolded cuticula. If it exists there, it is certainly a very much attenuated layer. I do not think that the elongated cells of the bulb can be regarded as modified hypodermal cells.

VI. Discussion.

1. Dorsal Cells.

The nature of the dorsal cells is not definitely determined, yet I have little doubt as to their nervous character. The interpretation of them as gland cells (Bürger, '91) seems to me untenable for many reasons. The cells do not have at all the appearance of gland cells, there is no trace of any secretion in the cell or its process, nor anything in this process which suggests even remotely a duct, and finally one finds no connection of the stalk with the intestine or with the exterior. Against the possibility that they may be *degenerate* gland cells, functional in larval life, it may be urged that there is absolutely no evidence of degeneration in the appearance of the cells.

If the positive evidence on the other side be examined, it will be found to be almost equally strong, and in favor of their nervous character. In the first place, their nuclei are like those of the large ganglion cells in affinity for stains, in the possession of one or two large homogeneous nucleoli, and in the curious unstained enclosures already described. On the other hand, it cannot be denied that the nuclear membrane is more irregular, and seems to be connected with the fibres of the cell substance, a condition which was not seen in the large ganglion cells.

The stalks of these cells certainly resemble nervous processes optically, as well as in their relation to the cell body, and in their termination, which has been considered in detail. Unless one regards the stalk as differentiated into a stainable and a non-stainable portion on account of some unknown difference in the chemical nature of the parts, it must be granted, I think, from the evidence previously produced, that the process branches at or near its termination in the brain. This branching seems to me to be an insuperable objection to the interpretation of these cells as glandular, and indeed to render it almost certain that they are nervous. Their enormous size and extremely fluid contents may be due to the freedom for growth which they enjoy in an unrestricted space, and, in part at least, to osmotic conditions.

Since in the ripe individual the mass of sexual products whch fills the body cavity would exert a dangerous or even fatal pressure on cells so delicate as these, it is evident that the partition is absolutely necessary for their development, and may be so for the protection of the brain. While the presence of the partition is essential to the existence of these cells as they are, it is impossible from the evidence at hand to form any idea of the cause which led to its development. However, the partition being formed, I believe it is possible to understand how the large cells may have attained their size and position.

It has already been mentioned that the dorsal cells vary considerably in size; an early sketch of a living animal, made before the structure was well understood, shows in a dorsal view, not two, but three successive pairs of large cells. There were, however, in this case, actually only two pairs of dorsal cells, and the supposed third pair was the most posterior pair of large ganglion cells in the brain. It has already been said of these that they are located, not *in* the mass of the brain, but in great part *above* it. Now, given two pairs of lateral cells located on the upper surface of the brain anterior to the fifth pair of ganglion cells near the place where the processes of the dorsal cells enter the brain mass, it is easy to conceive how they may have become larger and larger, and finally may have risen entirely above the brain into the free space dorsal to the œsophagus, where no obstacle is offered to their further increase in size. At the same time, the stalk would be produced as a mere mechanical result of the lengthening of the cell process to accompany this migration. Once free in this cavity there is every reason to believe that the cell might continue to develop in size until, with its companions, it should occupy the entire space, which is approximately the present condition of affairs. The fifth pair of large ganglion cells in the brain, half projecting, as they do, above its surface, would then represent the first stage in the migration which the dorsal cells have already accomplished. Attention must be called to the fact that the three pairs of cells which have been compared in this hypothetical statement of the case are not similar in one important particular; for whereas the processes of the fifth pair of ganglion cells are unbranched and may be traced far posteriad through the ventral nerve cord, the processes of the dorsal cells are branched and can be traced only a comparatively short distance. I do not see, however, that this difference greatly affects my explanation, — which is purely mechanical, — since the cell and not the process is directly concerned. The nuclei of both kinds of cells are nearly equal in size and alike in structure. The great difference be-

tween the two is due to the preponderance of the cell body in the dorsal cells, which I have assumed to increase by virtue of its changed surroundings. A similar difference in the size of the cell body is found between the fifth pair of ganglion cells, half projecting above the surface of the brain, and the first pair, which is deeply embedded in its substance.

One further point of interest suggests itself. It has already been mentioned that the commissural cells vary in position, being in many cases higher on the commissure than in others. If there be a tendency toward a more dorsal position in this case as well, — which on the basis of free space for development is more probable than the opposite movement, — then there are two distinct ways in which originally ventral elements may reach a dorsal position; first by the independent dorsal migration of superficially located ganglion cells, and secondly by a movement of commissural cells dorsad along the commissure. The first method is illustrated in the case of the dorsal cells, the second in the case of the commissural cells (the third pair). In both instances the cause of the migration may well be gain in nourishment and vigor as such cells advance more and more into the free space above the brain mass. If such a change in position involve a gain in vigor on the part of the cells concerned, then the origin of a dorsal ganglion from a simple commissure by the dorsal migration of elements either independently or along the commissure may be easily conceived, since around the ganglion cells which have acquired this position other nervous elements will collect with the increase in the amount of nervous matter accompanying the development of the nervous system. In this way, then, lateral and dorsal ganglia may arise.

If the brain of Nectonema shows distantly how the higher development may be reached, it shows still more clearly its immediate relation to the ventral nerve cord. The anterior ganglionic mass may be viewed as a differentiation of the anterior portion of the cord. The agreement between the portions of the brain and the three bundles of the cord has already been emphasized. It remains to call attention to the correspondence in the location of ganglion cells. As it was true of the cord that ganglion cells were found on the borders of the three fibrous tracts, so it is correct to say of the brain that the ganglion cells are developed on the edges of the corresponding tracts. This will be easily seen if, in a comparison of Figures 72–88 (Plate VI), one proceeds from behind forward; and it is still more evident when the vertical bands of fibres are taken into account; the fibres are, however, not represented in these figures.

2. Large Ganglion Cells.

The large ganglionic cells of the brain and ventral nerve cord were called by Bürger "giant cells." So far as mere size is concerned, the name is well chosen, but it has been pre-empted for the neurochord cells of higher groups. To avoid the confusion which has entered into other divisions of morphology owing to the use of a single name for a multiplicity of organs, this designation should not be employed here unless there is some reason for regarding them as homologous with the cells of Annelids and Crustacea which first received the name. In comparing these large cells with the neurochord cells of Annelids, the first point of difference to be noted is the number of the former. There are, as we have seen, at least five pairs of such cells in the brain and others along the ventral nerve cord. In the Nemertines, as in the Annelids, there is only a single pair of neurochord cells in the brain; and those in the ventral nerve cord are distributed in pairs and at regular intervals, which does not seem to be the case in Nectonema.

The second prominent point of dissimilarity has to do with the processes. The fibres of these large cells vary somewhat in size, and do not possess any very definite shape, being now nearly round, now angular, with a variety of form which may, however, be in part due to the effect of reagents. In optical appearance and in reaction toward staining fluids they recall strongly the neurochords or giant fibres of higher groups. They also extend for long distances, perhaps the entire length of the worm, in an unbranched condition. But they differ from the giant fibres in one striking respect, — they have no sheath; in fact, it is very difficult to say that they are even enclosed by a delicate membrane, so fine is the boundary between them and the surrounding tissue. On the other hand, the sheath of the giant fibres is the most striking peculiarity which they possess, and often exceeds in prominence the fibre itself.

These seem to me sufficient reasons for regarding the cells in question as not homologous with the giant cells of other groups. I have therefore avoided using the expression "giant cells" to designate them, in order not to suggest a false homology. It cannot be denied that these may represent the primitive form of the giant cells, in which the fibres have not yet acquired the highly differentiated sheath; but until this becomes more probable by reason of evidence as yet lacking, it is better to use the non-committal term, and to designate them as large ganglion cells.

3. Rows of Hairs.

The lateral rows of hairs are evidently developed in connection with the free life of Nectonema. Moreover, they are not structures without a parallel among the Nematodes. Many forms have been described with hairs distributed irregularly or regularly — sometimes in rows (Trichoderma) — over the surface of the body. Unfortunately, in such cases little or no idea has been given of the size and structure of the "hairs" by the authors who have mentioned them. In one form at least, the peculiar free-living marine genus Chætosoma (Giard et Barrois, '75), there is found a double row of hairs along a portion of the ventral line. The setæ are hollow and entirely superficial, thus agreeing in several points with those of Nectonema; they are not, however, so extended in their distribution as in the latter form.

4. Muscular Layer.

The complete degeneration of the posterior portion of the alimentary canal in the adult, as well as its minute size in comparison with the body of the worm, makes it at once evident that this organ cannot be functional in the adult. The question then suggests itself as to the source of nourishment during this period of life. As has been already noted, the protoplasmic zone of the muscular layer is thicker in the immature individual, and diminishes in thickness with the attainment of sexual maturity. This decrease in volume may take place in two ways, — by the formation of corpuscles directly from the cells of the layer, and by the giving up of food matter to neighboring cells or to the cœlomic fluid and thus to all tissues of the body.

As has been shown, the corpuscles of the body cavity probably originate from the cells of this layer by a process of abstriction. This process is never very extensive, so far as I have been able to judge, and hence will hardly serve to explain entirely the decrease in the volume of the layer. One is, therefore, compelled to accept the second method suggested, that of the indirect transmission of food matter either through neighboring cells to remote tissues, or by means of the fluid in the body cavity. The unusually large size of the protoplasmic portion of the muscle cells, and its granular condition, are well explained on the supposition that these cells have secondarily acquired the function of storing up nourishment for the support of the body during the period of adult life.

5. Parasitic Nature.

Nectonema possesses neither eye spots nor sense organs, such as are present in practically all cases of free-living, and especially of pelagic forms. The general structure of the alimentary tract, its diminutive size as compared with that of the animal, its occasional closure anteriorly, the complete degeneration of its posterior portion, and the absence of any functional anus, speak even more strongly against the possibility of regarding Nectonema as primarily a free form, and practically force one to the conclusion that it is a parasite, which passes its larval life in some unknown animal, wandering out of its host at sexual maturity and passing the final stage of its life history in a free condition, in which alone it is at present known. On the analogy of Gordius, the host may be surmised to be some fish or crustacean, and, since Nectonema is not so rare as has been supposed, it ought not to be difficult in its proper home to discover its host.

There are certain facts which should be mentioned in this connection. As has already been said, Nectonema was caught only on an ebbing tide and in the bay near shore, not in open water. And although a large amount of truly pelagic material was obtained in the same manner, yet numerous Annelids which are by no means truly pelagic were found in the same towing. The latter form part of the bay or shore fauna which in towing near the land is habitually found in the net. In the same way, Nectonema, which is probably set free from some one or more of the small fish or Crustacea which inhabit the shores of the bays or shallow water in general, will live normally in the little coves and quiet places along shore, but may be carried out by the tidal currents even to some distance. It is probably found at or near the surface at night only, and at the bottom during the day. The greater prominence of the contractile portion of the muscular layer in the male would seem to indicate that it is the more active of the two, and to this may be due in part the much larger number of males captured.

VII. Comparison with other Forms.

Numerous possible relationships have been suggested for Nectonema, many of which rest upon resemblances of a superficial character, such as the comparison with Sagitta on the ground that both possess lateral fins. Bürger ('91, p. 650) has sufficiently shown the fallacy of any comparison with Eubostrichus, which resembles Nectonema at most in

possessing external hairs! It is an interesting and at once a significant fact that Chætosoma possesses a double row of hollow hairs or bristles on a portion of the ventral line. These hairs strongly resemble those of Nectonema, but it is apparent at once from a comparison of internal organs that the resemblance is purely superficial, since Chætosoma is as like the Nematodes *s. str.* as Nectonema is different from them; this is simply an interesting case of the development of like structures in widely different forms, which may be traced perhaps to similarity in their conditions of life.

In much the same way the resemblance to the Trichotrachelidæ emphasized by Bürger ('91, p. 649) is at most an instance of the convergence of parasitic types. The resemblance is indeed close in the muscular and digestive systems. The latter is, however, the system most immediately and directly affected by parasitism, and such resemblances may easily have arisen independently in any number of animals. The peculiar structure of the œsophagus is shared by the Mermithidæ as well; and so far as the muscles are concerned this type is common to an entire group of Nematodes, the Cœlomyaria. On the other hand, the reproductive and nervous systems of Nectonema and the Mermithidæ represent opposite extremes in the class Nematoda.

There is one comparison, however, which deserves more detailed consideration. Verrill ('73, p. 632) said of Nectonema, "In general appearance when living and moving, it resembles Gordius"; and again ('79, p. 187) he calls attention to the external similarity of the living animals. Bürger ('91, p. 649) enumerates the points of agreement between the two as the absence of lateral lines and the position of the nervous system in the ventral line, and emphasizes the difference in the digestive system and in the structure of the muscles. This is not a sufficiently broad and accurate comparison, and it will be valuable to enumerate here more exactly the points of agreement and difference for the various systems of organs in order.

The cuticula differs both in thickness and in the possession of rows of bristles and scales in the one form, and of scattered papillæ and sensory bristles in the other. The subcuticula has in both the characteristic Nematode nature. The muscular elements show at first sight a considerable difference in structure, yet I am convinced that this is more apparent than real. The muscle cells of Nectonema are those of the typical Cœlomyarian, in which the muscle fibrillæ are arranged in a peripheral ∩-shaped layer about the distal edge of the muscle cell. Into the hollow of this contractile portion extends a projection from the plasmatic portion of the cell which is found at the inner border of the

contractile portion. If now we conceive this plasmatic portion to be reduced to a minimum, the form of muscle cell characteristic of Gordius will be reached; for in this genus the projecting protoplasmic portion is entirely lacking, the layer of contractile fibrillæ surrounds the entire cell, and the nucleus is found in the thin strip of plasma which occupies the centre. Not only do we find in a typical Cœlomyarian cells in which the plasmatic cell body hardly projects beyond the contractile layer, but I have also been able to find in cross sections of Gordius *sp.?* certain regions where the fibrillar layer in the proximal portion of the cell differs in thickness and in refractive power from that in the distal portion. I do not believe, therefore, that the difference in the muscular systems is so great as has been maintained.

To consider the second objection urged by Bürger against the relationship of Gordius and Nectonema, namely, the structure of the intestine, it will be necessary to make a short digression to consider the structure of the alimentary canal, and especially of the œsophagus, in Nematodes. Most text-books recognize only one type of œsophagus in this group, a muscular organ with a more or less triangular lumen lined with chitin, from which muscle fibres radiate perpendicularly to the long axis of the tube. This organ evidently acts like a suction pump in taking up nourishment.

If, however, one examines the literature on the group, it is evident that there are a number of families to which this description will not apply, and that there is really a second well marked type of œsophagus. This consists of a minute chitinous tube extending through a cell, or row of cells, with which no muscle fibres are connected. Evidently there is here no means of varying the size of the lumen. I believe the œsophagus in every family of Nematodes may be reduced to the one type or the other. The larger number of forms show the first, but in the Trichotrachelidæ and Mermithidæ the œsophagus is constructed on the second type, as is also the case in Nectonema. In Gordius this organ is found to be highly degenerate, and in certain species, or in specimens of a certain age, has entirely disappeared. Its condition appears to be different according to the descriptions given; but in a specimen collected in Cambridge there is absolutely no trace of an œsophagus in a perfect series of transverse sections. From the account of Vejdovský ('86, p. 404) it is at once evident that the œsophagus does not belong to the first type, and according to his description[1] and figures ('86, p. 404, Taf. XV. Fig. 35) it bears a

[1] Vejdovský says (p. 404): "Als Mundhöhle bezeichne ich das enge Kanälchen," etc. It is this portion of the alimentary canal which I regard as the morphological equivalent of the œsophagus of the second type.

strong resemblance to the second type. At any rate, I am unable to see the striking difference in this region on which Bürger lays great stress. As for the intestine proper, it is not of great importance whether the lumen be bounded by four or eight cells. There are evidently differences in the alimentary canal of the two forms; one of the most striking is the degeneration of the anterior portion in Gordius, and of the posterior part in Nectonema. This is, however, of minor importance on the question of general relationship.

At first sight nothing could appear more unlike than the reproductive systems in the two forms, and so far as external sexual organs are concerned there does exist a great difference. The papilla and terminal opening of the male Nectonema do not resemble in the least the forked tail and subterminal opening of Gordius. The female organs bear an external resemblance, but internally there is nothing in Nectonema parallel to the complicated structure of the system in Gordius. Too little is known of ovaries or testes in Nectonema to permit of a comparison, but the apparent absence of mesenteries and the probability that the organs are not paired in this case are certainly important differences. On the other hand, certain striking points of similarity must be noticed. The position of the sexual organs dorsal to the intestine is a peculiarity in Nectonoma which is shared only by Gordius among all the Nematodes at least. The same may be said of the fact that both male and female sexual organs possess terminal or subterminal openings. If my conjecture be correct that in Nectonema this is a cloacal opening, then this feature is also common to both. Moreover, of all Nematodes these two families are the only ones in which spicula are entirely wanting.

The body cavity in the two forms differs in that a lining epithelium is present in Gordius, but probably absent in Nectonema, except in the anterior chamber. The body cavity of both increases in size, however, by the cell masses which bound it taking part in the formation of sexual products or the nourishment of the body; but it is doubtful if this process goes so far in Nectonema as in Gordius, where it leaves only a thin row of cells, the peritoneal epithelium. This matter is, however, hardly cleared up for Gordius, even after the numerous investigations that have been made, and it cannot be regarded as more than formulated for Nectonema by the present study.

The lateral lines, as well as the contained excretory canals which are so characteristic of all other Nematodes, are wanting in both Nectonema and Gordius. In Gordius, moreover, no probable excretory system has

been shown to exist, and I have looked in vain for evidence of one in Nectonema. The only indication of a dorsal line in Gordius is the median dorsal interruption of the longitudinal muscles in the posterior portion of the body; in Nectonema, on the contrary, this organ is well developed. In both forms the ventral line is prominent, and in both it contains the ventral nerve cord.

Of the nervous system it may be said that the brain is more highly developed in Nectonema, the dorsal cells as well as the correlated anterior chamber being structures entirely without parallel in Gordius. But the ventral nerve cord in the two genera shows a similarity not only in position, but to a certain degree in structure, being made up in general of three portions, a median and two lateral. (Cf. Vejdovský, '86, Taf. XVI. Figs. 51, 63, *et al.*) Like many other Nematodes, both forms possess an anal ganglion.

Numerous lesser points of likeness may be mere coincidences. Such are the great numerical superiority of males over females, — which, among all Nematodes, is found only in these two groups, — the parasitic nature, and the mode of motion. The spermatozoa which I have described recall the unripe sperm of Gordius; yet such evidence is interesting rather than weighty.

In summing up this detailed consideration it may, I believe, fairly be said, that the points of difference between Gordius and Nectonema are more numerous than those of likeness, but that the latter are more general and important. This agreement in general characters is so striking that I cannot believe it is due to anything else than affinity. It will be noticed that the characters which separate the Gordiidæ from the other Nematodes are shared with Nectonema; thus the absence of lateral lines, the existence of *one* principal nerve cord (ventral), the dorsal position of the sexual organs, and the terminal openings of the same. Again, the points of difference between the two groups are largely those which separate the various families of Nematodes *s. str.* from one another; namely, the structure of the muscles and alimentary canal (?), and the character of the ducts and external sexual organs.

We do not know how much the change from salt to fresh water has modified Gordius, which is evidently the more degenerate form, as may be inferred, for example, from the greater reduction of the alimentary canal and of the nervous system. Certainly the rows of bristles in Nectonema are to be attributed to its free life and more active habits. With the latter also one would naturally look for a more highly developed nervous system. Further evidence, that to be gained from the

embryonic development as well as from the life history and structure of the larva, will make this matter clearer.

Nearly all writers agree in placing the Gordiidæ in an isolated position under the Nematodes. If, according to the proposal of some, this family be raised to the dignity of a separate order, then there is no doubt in my mind of the right of Nectonema to a position in that order as the representative of a new family, the Nectonemidæ. But whatever may be the final decision in regard to the rank of the Gordiidæ, this new family must take its position near that group. That the relationship is close enough to warrant the inclusion of the genus Nectonema in the family of the Gordiidæ is hardly possible, but a final opinion on this point can be given only in the light of more complete knowledge, especially on the points just enumerated. It is my intention to investigate the subject further, and to follow if possible the life history of this most interesting form.

Cambridge, March 25, 1892.

BIBLIOGRAPHY.

Bürger, O.

'91. Zur Kenntniss von Nectonema agile, Verr. Zool. Jahrb. Abth. f. Anat. u. Ontog., Bd. IV. p. 631.

Fewkes, J. W.

'83. On the Development of Certain Worm Larvæ. Bull. Mus. Comp. Zoöl., Vol. XI. p. 167.

Giard, A., et Barrois, J.

'75. Note sur un Chætosoma et une Sagitta suivie de quelques reflexions sur la convergence des Types par la vie pélagique. Rév. de Sci. Nat. de Dubrueil, Tom. III. 20 pp.

Schneider, A.

'66. Monographie der Nematoden. Berlin. 357 pp.

Vejdovský, Fr.

'86. Zur Morphologie der Gordiiden. Zeitschr. f. wiss. Zool., Bd. XLIII. p. 369.

'88. Studien über Gordiiden. Zweite Mitth. Zeitschr. f. wiss. Zool., Bd. XLVI. p. 188.

Verrill, A. E.

'73. Report upon the Invertebrate Animals of Vineyard Sound, etc. Report U. S. Fish Com., 1871–72, p. 295.

'79. Notice of recent Additions to the Marine Invertebrata of the Northeastern Coast of America, etc. Proc. U. S. Nat. Mus., Vol. II. p. 165.

EXPLANATION OF FIGURES.

All figures were drawn with the aid of Zeiss lenses and an Abbé camera unless otherwise stated, and represent preparations of *Nectonema agile*, Verr. The method of staining, the lenses, and the magnification employed, are noted briefly for each figure.

ABBREVIATIONS.

cd. n. v.	ventral nerve cord.
cl. coms.	commissural cells of brain.
cl. d.	dorsal cell.
cl. gn. I, II., etc.	first, second, third, etc. large ganglion cell of brain.
cl. in. I.–IV.	intestinal cells I. to IV.
cl. mu.	muscle cell of body wall.
cl. œ.	œsophageal cell.
cl. sns.	sensory cell.
coms. œ.	dorsal (supra-œsophageal) commissure of brain.
cp′	corpuscle of body cavity fluid.
cta.	cuticula.
e'th. pi"t.	peritoneal epithelium.
fbr′. mu.	contractile fibrillæ of muscle cell.
fbr. n.	nervous fibrillæ.
gn. an.	anal ganglion.
h'drm.	hypodermis.
in.	intestine.
ln. d.	dorsal line.
ln. v.	ventral line.
mb. ba.	basement membrane.
n. a.	nerve fibres anterior to brain.
nl. d.	nucleus of dorsal cell.
nl. gn.	nucleus of large ganglion cell.
nl. gn. I.–V.	nuclei of ganglion cells I. to V. of brain.
n. l.	lateral nerve of ventral nerve cord.
nll.	nucleolus.
n. m.	median nerve of ventral nerve cord.
n. n.	nervous nuclei.
œ.	œsophagus.
pd. cl. d.	stalk of dorsal cell.
pr'c. gn.	process of ganglion cell.
sac. d.	dorsal sac.
sp'z.	spermatozoa.
st. pi"ph.	peripheral layer of anal ganglion.
te.	testis.
va. df.	vas deferens.

PLATE I.

Fig. 1. Male Nectonema, natural size. The bristles are so minute that they could not be represented in proper proportions. Free hand drawing.

Fig. 1^{a}. Anterior end of the same to show torsion of the body. Somewhat diagrammatic.

Fig. 2. Dorsal view of anterior end of living animal. × 32.

Fig. 3. Lateral view of anterior portion of living animal. Drawn by A. Agassiz, August 5, 1871.

Fig. 4. Posterior portion of male. Drawn from specimen cleared in clove oil. Simple microscope. × 7.

Fig. 5. Posterior portion of female discharging eggs. Drawn from specimen cleared in clove oil. Simple microscope. × 7.

Fig. 6. Lateral aspect of central part of body. Drawn by A. Agassiz, August 2, 1877.

Fig. 7. Ventral aspect of body. Drawn from living animal, and afterwards reduced one half. 1. A. × $\frac{6}{2}^{2}$.

Fig. 8. Right half of anterior portion of the body drawn from a transparent object in clove oil, and represented as though the near (left) half of the body had been removed. 1. A. × 48.

Fig. 9. End of body of male viewed as a transparent object in clove oil. 2. a*. × 17.

Fig. 10. End of body of female viewed as a transparent object in clove oil. 2. A. × 50.

Fig. 11. Cross section from centre of body of male. Kleinenberg's hæmatoxylin. 2. A. × 98.

PLATE II.

Fig. 12. Tangential section, including cuticula of dorsal line with bristles. 1. C. × 180.

Fig. 13. Cross section of cuticula with bristles attached, only the basal portions of which are represented. At the lower side lies a cross section of a bristle. 4. C. × 400.

Fig. 14. Cross section of cuticula with scales attached. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 15. Cross section of scale with cuticula and hypoderm. Apochr. 4 mm. Compens. Oc. 12. × 1,050.

Figs. 16, 17. Cross sections of scale on cuticula to show central canal. Apochr. 4 mm. Compens. Oc. 4. × 360.

Figs. 18, 19. Surface view of scales on cuticula. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 20. Cross section of cuticula and hypoderm. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 720.

Fig. 21. Cross section of body wall just lateral to dorsal line to show structure of the muscles. Apochr. 4 mm. Compens. Oc. 8. × 720.

Fig. 22. Fragment of muscle after maceration in 60 % KOH, and subsequent treatment with potassic acetate. 3. C. × 320.

Figs. 23–26. Cross sections of body wall from different individuals to show the different widths of the contractile and protoplasmic zones in the muscular layer. The contractile zone is represented by a dark band, and the protoplasmic by a lighter tint. 1 A. × 52.

Fig. 27. Tailed nuclei from muscular layer. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 8. × 720.

Figs. 28–30. Portions from protoplasmic zone of muscular layer, showing the formation of corpuscles from the free ends of the muscle (?) cells. Gentian violet and eosin. Apochr. 4 mm. Compens. Oc. 4. × 375.

Fig. 28. Portion of cell nearly cut off at *x*.

Fig. 29. Portion of cell at *x*, which stains more deeply and resembles corpuscles (*cp'*.) of the body cavity.

Fig. 30. Corpuscles of different sizes completely separated from protoplasmic zone.

PLATE III.

Figs. 31–45. Transverse sections of the alimentary canal from a single series of sections. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 4. × 230.

Fig. 31. 7th section of the series.
" 32. 16th " " "
" 33. 25th " " "
" 34. 31st " " "
" 35. 32d " " "
" 36 38th " " "
" 37. 47th " " "
" 38. 48th " " "
" 39. 49th " " "
" 40. 50th " " "
" 41. 51st " " "
" 42. 52d " " "
" 43. 54th " " "
" 44. 55th " " "
" 45. 103d " " "

Figs. 46–48. Transverse sections of alimentary canal from the region where it is bounded by two cells alone to show diminution in size toward the posterior end. Apochr. 4 mm. Compens. Oc. 4. × 230.

Fig. 46. Kleinenberg's hæmatoxylin.

Figs. 47, 48. Ehrlich's hæmatoxylin.

Fig. 49. Transverse section of alimentary canal to show the normal relation of the lumen to the cells. Kleinenberg's hæmatoxylin. 2. E. × 610.

Figs. 50, 51. Transverse sections of the œsophageal cell in the same series. Ehrlich's hæmatoxylin. 2. E. × 610.

Fig. 50. To show the relation of the nucleus to the chitinous tube.

Fig. 51. Two sections beyond the section in Fig. 50 to show disappearance of the chitinous tube.

Fig. 52. Lateral aspect of intestine. The two cells of the opposite side are not shown. Ehrlich's hæmatoxylin. 2. C. × 165.

PLATE IV.

Fig. 53. Posterior end of male viewed as a transparent object in clove oil. 2. C × 165.

Fig. 54. Wall of dorsal sac showing nuclei. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 55. Spermatozoa (unripe ?). Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 12. × 1,000.

Fig. 56. Posterior end of female viewed as a transparent object in clove oil. 2. A. × 95.

Fig. 57. Sagittal section through posterior end of female, showing slight development of anal ganglion. Ehrlich's hæmatoxylin. 2. A. × 95.

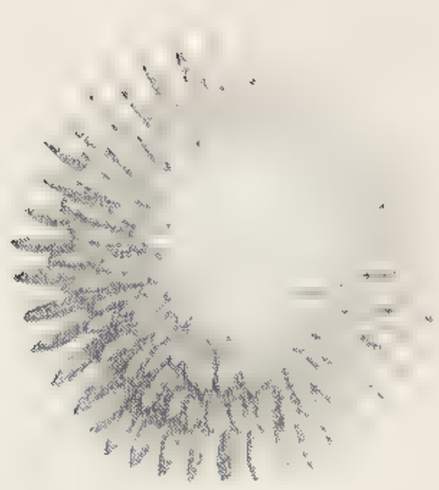
Fig. 58. Transverse section through middle of body of female filled with eggs. Böhmer's hæmatoxylin. 3. A. × 130.

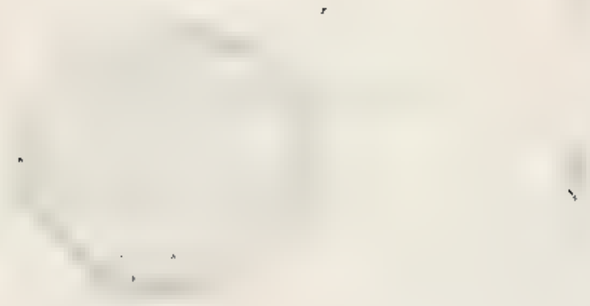
Fig. 59. Transverse section through body wall of nearly mature female to show remains of cell layer (*) within the muscular layer. Böhmer's hæmatoxylin. 3. C. × 330.

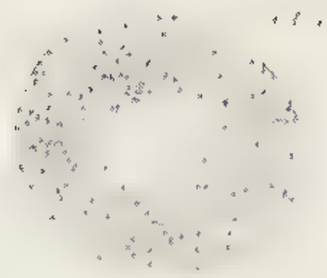
Fig. 60. Section of immature egg. Ehrlich's hæmatoxylin. 3. D. × 540.

Fig. 61. Section through nearly ripe egg. Böhmer's hæmatoxylin. 3. D. × 540.

Fig. 62. Egg after contact with sea-water. Glycerine preparation. 3. D. × 560.







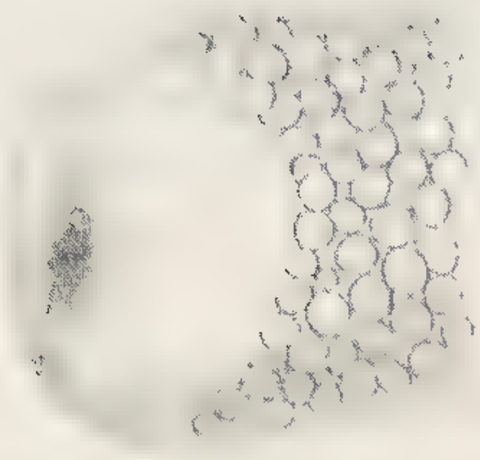


PLATE V.

Fig. 63. Ventral aspect of head with brain, viewed as a transparent object in clove oil. 2. C. × 160.

Fig. 64. Nucleus of dorsal cell showing enclosed body (*x*). Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 680.

Fig. 65. Nucleus of dorsal cell. Kleinenberg's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 680.

Fig. 66. More regular nucleus of dorsal cell. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 67. Oblique section through basal portion of dorsal cell where the process enters and divides. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 68. Small nervous nuclei of brain. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 69. Nucleus of commissural cell showing enclosure similar to that of the dorsal cell. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 70. Nucleus of large ganglion cell in anal ganglion. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 71. Nuclei of cells in peripheral layer of anal ganglion. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

PLATE VI.

Figs. 72–88. Successive transverse sections through the brain. The small nervous nuclei are represented by simple dots, the nuclei of the large cells as accurately as possible; the cell bodies are not represented.

Fig. 72 is the twelfth section from the apex of the head; each section is represented from its anterior face, and approximates 10 μ in thickness. Ehrlich's hæmatoxylin. 2. A. $\times$ 95.

Fig. 89. The posterior end of the male with anal ganglion and dorsal sac viewed as a transparent object in clove oil. Only a few of the numerous Gregarinida (*) in the body cavity are represented. 2. A. $\times$ 66.

PLATE VII.

Fig. 90. Sagittal section through posterior end of male, slightly lateral, showing large cells and processes in anal ganglion. Böhmer's hæmatoxylin. 1. C. × 180.

Fig. 91. Gregarinida from mass of spermatozoa. One in cross section is shown at *a*. Mayer's HCl carmine. 3. D. × 560.

Fig. 92. Transverse section, slightly oblique, from near the tip of the head, showing sensory cells, and nerve fibres passing up towards them. Ehrlich's hæmatoxylin. 2. C. × 230.

Fig. 93. Isolated sensory cells from front end of head. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 94. Diagrammatic representation of the relative size and position of the large ganglion cells in the brain. The extremes of variation in the position of the second pair (*cl. gn.* II.) are represented on the right and left of the figure. Dorsal aspect with the dorsal cells removed; the deep-lying cells appear fainter, cells which are nearer being more prominent. Drawing by A. G. Mayer.

Fig. 95. Oblique longitudinal section of posterior portion of the brain and the partition which cuts off the anterior chamber. The deepest and last portions of the processes of the dorsal cells are shown. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

PLATE VIII.

Fig. 96. Transverse section from posterior region of body of male. The dorsal margin is somewhat broken. Bismarck brown. 3. A. × 125.

Fig. 97. Longitudinal section of ventral nerve cord near the front end of the anal ganglion. Böhmer's hæmatoxylin. 1. C. × 180.

Fig. 98. Dorsal cell viewed as a transparent object in clove oil. The left half of the cell is occupied by a large vacuole. 2. D. × 290.

Fig. 99. Transverse section through dorsal cells and brain. The section is oblique enough to pass through the process of the first cell on the left, and of the second cell on the right. Mayer's HCl carmine. 2. D. × 290.

Fig. 100. Termination of process of right dorsal cell in Fig. 99 found 20 μ farther posteriad. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 101. Transverse section of ventral line with ventral nerve cord. Ehrlich's hæmatoxylin and eosin. Apochr. 4 mm. Compens. Oc. 4. × 250.

Fig. 102. Transverse section of dorsal line. Ehrlich's hæmatoxylin and eosin. Apochr. 4 mm. Compens. Oc. 4. × 250.

XXIX.

Preliminary Note on some Modifications of the Chromatophores of Fishes and Crustaceans. By Alexander Agassiz.

In a former paper on the Development of Flounders,[1] I have called attention to the rapidity with which young flounders adapt themselves to their surroundings, and have shown how soon their pigment cells, when young, assume in a general way the coloring of the bottom on which they rest. I have since that time experimented occasionally upon the effect of a black and of a white bottom upon other fishes, and upon Crustacea in the young stages of which there were huge or highly specialized pigment cells (chromatophores).

I was surprised to find that in adult specimens of Gasterosteus, for instance, the coloration was soon modified by keeping the fish upon a black or upon a white tile. A number of Gasterosteus were taken which showed but slight individual differences, and might have passed as presenting no perceptible contrast in their general coloring (Figs. 1, 2). They were divided into two sets, each set placed in a glass dish, one upon a bottom of black tiles, the other upon white tiles.

At the end of three days, there was already a very striking contrast between the coloration of the two sets of specimens. Those placed upon the black tiles had retained their original coloration, while those upon the white tiles assumed a grayish tint. The pigment cells of the darker bright-colored specimens consisted of two kinds of chromatophores, fully expanded (Figs. 1, 2). The uppermost cells were highly dendritic, with closely packed thin ramifications of a dark chocolate color, with nearly black nuclear centre; the lower chromatophores were more compact, with flatter and spreading ramifications a short distance from the centre. In the specimens which had become bleached, on the contrary, the chromatophores were reduced to mere dots, with

[1] On the Young Stages of Bony Fishes. By Alexander Agassiz. I. The Development of Flounders. Proc. Am. Acad., Vol. XIV. p. 1. Boston, 1878–79.

here and there an amœbiform thread extending from the central nucleus (Fig. 3). If the bleached specimens were kept continuously upon the white tile for five to six weeks, they apparently lost the faculty of regaining their original coloring. When removed to a background of black tiles, specimens which had been submitted to the action of the light of the white tiles for only from three to ten days regained to a great extent their original coloration, though never its primitive brilliancy; while the specimens which had been bleached for a longer time seemed to have become permanent albinos, or grayish lighter colored specimens. The pigment cells no longer expanded and contracted under the influence of varying conditions of intensity of light, as they do when they have not been too long subjected to one set of strong influences.

Our common Ctenolabrus varies, as is well known, greatly in coloration. But the conditions which bring about the differences described are seen only in the young from the time they hatch until they are not more than from about four to five months old. The shade of coloring is brought about by the greater or less development of the pigment cells, which assume either the form of a thin grayish film, with an annular nucleus, the film consisting of comparatively short, broad amœbiform expansions, giving to the fish a gray appearance if spread uniformly over the surface, or of gray patches or bands if limited to special areas (Fig. 5). Should the black chromatophores be more concentrated, and its offshoots thinner but more numerous, and packed together as they are in Figure 4, the young fish would appear to have a much darker tint, and from the reduction of these chromatophores to mere dots, with the presence only of the larger black chromatophores on the upper edge of the alimentary canal, and near the tail, the fish assumes an entirely different aspect, being comparatively transparent and colorless.

Experiments made with the youngest stages of Ctenolabrus and of Platessa have shown the same results. A number of specimens of each species were picked out as soon as hatched, and placed respectively upon black and white tiles. The young of Ctenolabrus and of Platessa at these early stages have only black pigment cells, so that the effect of light is not complicated by the interference of other colored cells.

After ten days, the young of Ctenolabrus placed upon the white tiles were found to develop only into practically colorless stages, such as are figured in Figures 1, 2, and 4 of Plate XIV. of the Young Osseous Fishes, Part III.,[1] while those which were placed upon black tiles

[1] Proc. Am. Acad., Vol. XVII. p. 271. 1882.

developed into young with well marked black pigment cells of the type of those of Figures 2 and 5 of the same plate.

With Platessa, the young kept on dark tiles passed into stages with well marked black pigment cells, while in the specimens kept on white tiles the pigment cells were reduced to a minimum, — to mere circular dots.

In the case of Hemitripterus americanus, in which the reddish pigment cells play a more important part, the young kept upon white tiles will assume the appearance of such types as are figured on Plate III. Figures 8, 9, of Agassiz and Whitman's Development of Osseous Fishes, Part I.,[1] while in those kept upon black tiles the black pigment spots develop in a marked manner, and form an upper layer of large regularly dendritic chromatophores on the flanks of the body. See Figures 10, 11, of the same plate. The yellowish-red colored cells are not as much affected by the color of the ground as was found to be the case in the colored cells of the young of Ctenolabrus.

The color of the fish is due to differently colored chromatophores placed on a lower level than the black pigment cells. These may be red, yellow, brown, blue, or other color, and by their combination and the greater or less prominence of a special set of chromatophores will give to the young fish its prevailing tint, which may be distributed in a general tone, or in patches and bands on the side of the body or head.

On keeping selected lots of young specimens of Ctenolabrus, probably two months old, of various coloring, upon black and white tiles (Figs. 8–16), the results were found to be similar to those obtained with the older Gasterosteus. Only the faculty of recovering their original color was evidently not so easily lost as in the case of the older Gasterosteus. This would seem to indicate that to retain a condition of coloring brought about or modified by surrounding influences, the young fish must remain exposed to them for a considerable time, and the modification will be more or less permanent, or of a greater or less degree, according to the age of the fish.

The young fishes placed upon black tiles retained their brilliant coloring, no matter whether red, yellow, brown, or blue chromatophores were present; and neither they nor the black pigment cells were modified by the light reflected from the black tiles (Fig. 16). On the other hand, the young fishes kept for ten days upon white tiles had lost, in proportion to their original dark tint, much of their dark color, the black pigment cells having become reduced in some of them to mere dots, in others

[1] Mem. Mus. Comp. Zoöl., Vol. XIV. No. 1, Part I. 1885.

to faint nuclei, with their delicate radiating spokes indicating faintly the former extension of the dark chromatophores (Figs. 11–15). The colored pigment cells seem to be far less influenced by the color of the bottom upon which the young fishes are placed; they contract somewhat, but are never reduced in size as much, or in the same proportion, as are the black cells. (Compare Figures 9 and 16.) The question of heredity involved in the changes due to the growth of flounders from a symmetrical embryo to an unsymmetrical adult, are naturally suggested by the development of the flounder. They have an important bearing on the transmission of acquired character, and seem to have escaped the notice of most writers on the subject.

In the case of young Lobsters, while still pelagic, the changes in coloring were quite marked; they pass, during the first month of their growth, from green to brown, but thus far my attempts to change or modify their coloring by the action of differently colored bottoms have not been successful. Nor have I succeeded any better with the young embryonic stages of Crangon and Palæmon, in which the tail and thorax are marked by few large and prominent pigment cells. The Crustaceans were kept, during parts of several seasons, subject to very different influences of light and surroundings, but without producing any perceptible change in coloration.

December, 1892.

EXPLANATION OF THE PLATE.

Fig. 1. Pigmented area near the centre of the lateral line of adult Gasterosteus, showing the upper and the lower layer of chromatophores fully expanded.

Fig. 2. One of the chromatophores of the upper and the lower layer. The cell with expanded ramifications belongs to the upper layer. From the same area as those of Figure 1.

Fig. 3. Pigmented area of the same portion as that of Figure 1, taken from a fish which had been kept upon a bottom of white tiles, showing the contracted chromatophores.

Fig. 4. Expanded surface chromatophores of a pigmented band on the flanks of a young Ctenolabrus, measuring about 5 mm. in length.

Fig. 5. Expanded chromatophores of the opercular area of a young Ctenolabrus, somewhat older than the fish represented in Figure 4.

Fig. 6. Large single chromatophore near the tail of a young Ctenolabrus of the age of Figure 4, fully expanded.

Fig. 7. Chromatophores of a young Ctenolabrus taken from near the centre of the lateral line, showing the black cells contracted and closely packed together.

Figs. 4–7. From young fishes caught in the tow-nets and subsequently kept on bottoms of black and white tiles.

Fig. 8. Pigmented area of flank of a gray Ctenolabrus, which had been kept on white tiles for twelve days.

Fig. 9. A similar pigmented area from a young Ctenolabrus, which had been kept on a white tile bottom for ten days, and then placed for the same length of time on a black tile bottom. It had by no means recovered the dark appearance which the same area presented after being exposed to the action of light from a black tile for ten days. See Figure 16.

Fig. 10 Pigmented area exposed to the action of the light from a white tile bottom for ten days. The black cells alone show changes; the colored cells do not differ from those of similar areas exposed upon a bottom of black tiles.

Figs. 11–15. Different views of the same pigmented area in several young specimens of Ctenolabrus, after being exposed to the action of the light upon a bottom of white tiles for about thirteen days.

Fig. 16. The same pigmented area of a young Ctenolabrus, exposed upon a bottom of black tiles for ten days. The black pigment cells are intensely black, and the red cells somewhat more expanded than in Figure 10, and much less so than in the same areas exposed upon a bottom of white tiles for thirteen days. See Figures 11–15.

No. 5. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in Charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., *Commanding.*

III.

On a peculiar Type of Arenaceous Foraminifer from the American Tropical Pacific, NEUSINA[1] AGASSIZI. By A. GOËS.

AMONGST the vast number of remarkable forms from the deep-sea fauna which Mr. Alexander Agassiz brought home last year from his important and successful expedition in the United States Fish Commission steamer "Albatross," in the Pacific off Central America, the Galapagos Islands, and in the adjacent seas,[2] was found this stranger to the Foraminifera on record. Mr. Agassiz has had the kindness to send me for examination a large number of specimens, together with an extensive collection of other foraminiferous material, dredged during this cruise.

The most striking feature of Neusina is its stroma, which forms a strong network of bundles of very fine chitinous threads, measuring in thickness 0.003–0.006 mm., incorporated with a thin layer of finest sand and débris of shells. Although these inorganic constituents of the structure amount to about 80% of the weight of the whole after drying, the test preserved in spirit is to a certain degree flexible and flabby, but somewhat brittle, recalling somewhat the consistency of some fresh-water algæ belonging to the Nostoc family. It is only after drying and removing the sand grains and dust with a brush that the stroma comes to sight as a gray or yellowish flocculent felt. The meshes in the network measure in diameter from 0.05 to 0.08 mm. The test is leaf-formed, with outlines

[1] From *νέειν*, to spin

[2] Comp. Letter and Report by Alexander Agassiz, in Bull. Mus. Comp. Zoöl. of Harvard College, Vol. XXI. No 4 (1891), and Vol. XXIII. No. 1 (1892); and the Memoirs of the Mus. Comp. Zoöl., Vol. XVII. No. 2 (1892), On Calamocrinus Diomedæ, Agass.

usually describing a triangular, fan-like, or reniform figure, with more or less strongly arcuated edge, the whole reminding one of a Fadina alga of 0.5 to 2 mm. in thickness. Sometimes the shape is that of a biauriculated leaf, produced much more in breadth than in height. The edge is often undulated in broad folds, and sometimes new individuals sprout from the broad side, forming irregularly shaped clusters of two or three individuals.

The chambers constitute arcuated, concentric, more or less complete bands, increasing in length with age, forming a fan-like growth, commencing with a pointed triangular juvenile stage. Some of the chambers do not extend from side to side, but stop short after a while, ending in an acute point on the broad side.

The two ends of the chambers are usually produced in a narrow, more or less compressed, hollow appendage, with thin walls, composed of parallel bundles of threads, which also are incrusted, but more sparingly, by sand and débris. The cluster-like appendages often divide into two or three terminal branches. The longest measure about 20 mm., with a diameter of 1 to 2 mm.; their wall is only 0.05–0.06 mm. thick. Forming a row along the lower edge of the test, they serve probably as fastenings to the bottom, where they often are entangled in masses of a Rhizammina. The chamber wall is thin, often wrinkled, and here and there pierced by irregularly formed pores of different size. In some places a faint striation running perpendicular to the chamber sutures across the chamber wall can be discovered, probably indicating the divisions into chamberlets. The interstice between the two side walls is crossed by numberless irregular partitions, forming masses of small chambers of different size and form, giving to the structure a sponge-like texture. The color is commonly sooty, with shades in dark olive; when dried, it becomes grayish clay-colored.

The largest specimens measure about 190 mm. in breadth. On account of their brittleness, specimens in perfect condition are rarely obtained; usually the early stage is detached and the border torn. The appendicular tubes are often wanting, or some scanty remnants only left. Among the whole assemblage of specimens from the "Albatross" expedition, I have not found a single one with an embryo stage.

Habitat. — Pacific: Lat. 1° 7′ N., Long. 8° 4′ W. (about 35 miles W. N. W. off Galeras Point), in 3,097 meters' depth (1,740 fathoms); olive-green ooze; temperature, +2°.2 Cent. (Albatross Exp. Stat. 3,399.)

Lat. 10° 14′ N., Long. 96° 28′ W. (about 300 miles S. S. E. from Acapulco); depth, 3,972 meters (2,232 fathoms); green mud; temperature, +1°.7 Cent. (Albatross Exp. Stat. 3,414.)

Lat. 14° 46′ N., Long. 98° 40′ W. (about 95 miles S. E. from Acapulco); depth, 3,344 meters (1,879 fathoms); brown mud, with Globigerina; temperature, +2°.2 Cent. (Albatross Exp. Stat. 3,415.)

Affinities. — In a valuable paper (*Note sur un Foraminifère nouveau de la Côte Occidentale d'Afrique*, Mém. Soc. Zool. de France, Tom. III. p. 211, 1890), Mr. Ch. Schlumberger has described a type, under the name Jullienella fœtida, which seems to have much in common with Neusina, the principal difference being the absence of the filamentous stroma, and the more simple and regular subdivision in chamberlets by the former, which also is provided with tubes *all around* the edge. Jullienella has been dredged by M. le Docteur Jullien off the Liberian coast in four to five meters' depth.

As far as we know, these two forms stand much isolated from others of that class on record, — recent as well as fossil, — and justly claim to be placed in a family by themselves.

Kisa, Sweden, April, 1892.

EXPLANATION OF THE PLATE.

Figs. 1, 2. Neusina Agassizi, nat. size.

Fig. 3. The edge of the last chamber; nat. size.

Fig. 4. Part of the surface, showing its wrinkles and pores; in reflected light. $\times \frac{11}{1}$.

Fig. 5. Transverse section, showing the partitions and the small irregular chamberlets, the former made up chiefly of ovoid silicious bodies; in transmitted light. $\times \frac{11}{1}$.

Fig. 6. Network of chitinous threads forming the stroma of the test, after removal of the sand. $\times \frac{40}{1}$.

Fig. 7. The lower part of an appendicular tube, cleared from sand, showing its structure of bundles of threads. $\times \frac{8}{1}$.

Fig. 8. Transverse section of such a tube. $\times \frac{8}{1}$.

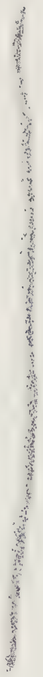
Fig. 9. Colored sketch, from a fresh specimen, made on board the "Albatross" by M. Westergren.

7.

6.

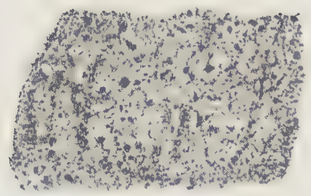
8.

3.



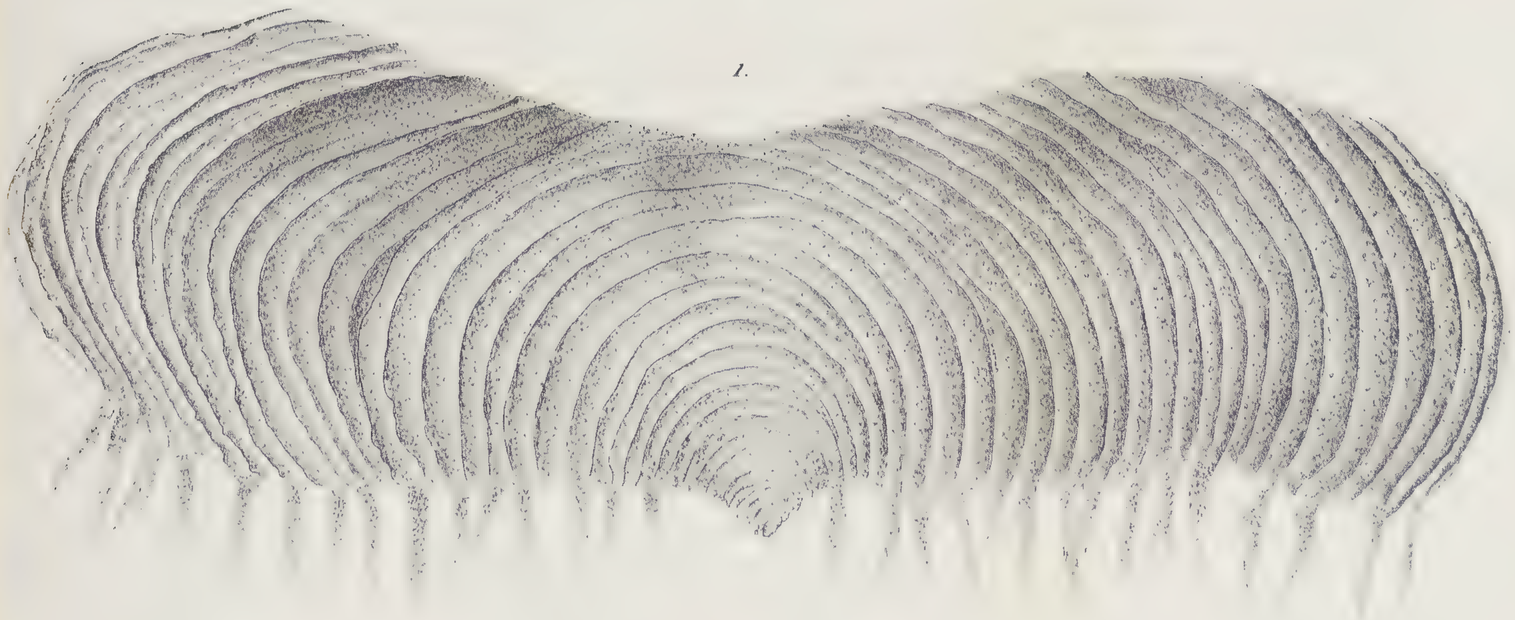
9.

4.

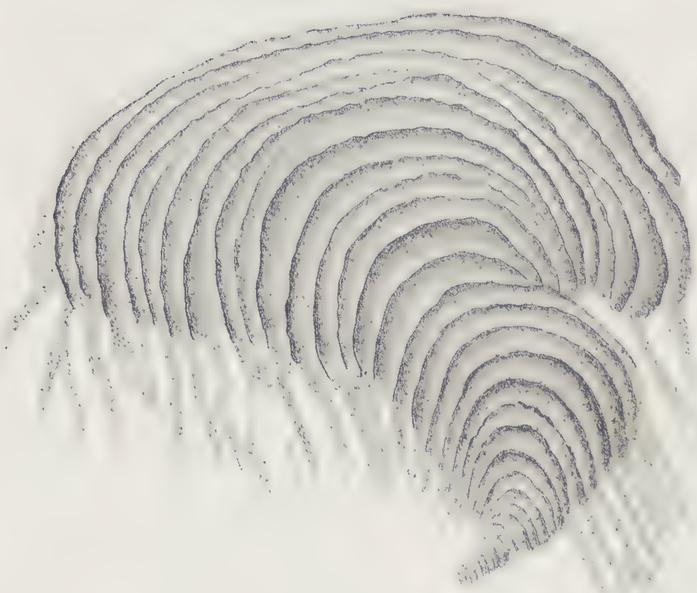


5.

1.



2.



A. Goes, del

No. 6. — *Reports on the Results of Dredging, under the Supervision of* ALEXANDER AGASSIZ, *in the Gulf of Mexico* (1877–78), *and in the Caribbean Sea* (1879–80), *and along the Atlantic Coast of the United States* (1880), *by the U. S. Coast Survey Steamer "Blake,"* LIEUT.-COMMANDER C. D. SIGSBEE, U. S. N., *and* COMMANDER J. R. BARTLETT, U. S. N., *Commanding.*

[Published by Permission of CARLISLE P. PATTERSON and J. E. HILGARD, Superintendent of the U. S. Coast and Geodetic Survey.]

XXXIV.

Report on the Mollusca dredged by the "Blake" in 1880, including Descriptions of several new Species. By KATHARINE JEANNETTE BUSH.

THIS collection, although a small one, is of considerable interest, owing to the fact that it contains a number of very beautiful, and hitherto undescribed species, and also because the range of many of our Northern forms is extended much farther south.

There were about fifty small jars and bottles of unassorted material from thirty-two stations off the coast included between George's Bank, N. Lat. 41° 35′ 15″, W. Long. 65° 51′ 25″, and Charleston, South Carolina, N. Lat. 32° 25′, W. Long. 77° 42′ 30″, ranging in depths from 24 to 1,394 fathoms. These stations are mostly in depths between 100 and 1,000 fathoms, there being but six in less than 100 fathoms, and six below 1,000 fathoms.

Of the eighty-six species found, about thirteen are named and described as new, and five others, although supposed to be undescribed, are so badly worn and broken that they are only worthy of brief mention.

All the specimens have been carefully compared with the types or typical forms in the collection of the U. S. Commission of Fish and Fisheries.

References are only given to those species included in Professor Verrill's catalogues of deep-water Mollusca (Transactions of the Connecti-

cut Academy of Arts and Sciences, Vols. V. and VI., 1882–1885), and Mr. Dall's reports on the "Blake" Mollusca (this Bulletin, Vols. IX., XII., and XVIII., 1881, 1886, and 1889). In some instances, where the name has been changed, a more complete synonymy is given.*

In order that the distribution of each species may be given as completely as possible, the range, as recorded in the Reports of the U. S. Commission of Fish and Fisheries, is included, and mention is also made of other known localities, north and south.

In giving the bathymetrical range, mention in most cases is made of the depths at which the species was found living, in addition to the extreme limit of range. When no distinction is made, it is to be understood that the specimens were taken alive.

At the end of this report, a list of the species is given, showing the relation of each to the Northern and Southern faunas.

My acknowledgments are especially due to Professor Agassiz for the privilege of preparing this paper, and to Professor Verrill for valuable advice and criticism.

* Other books used for reference are the following:—

Binney, W. G. Gould's Invertebrata of Massachusetts, 1870.

Bush, K. J. Report on Labrador Shells, Proceedings of the U. S. National Museum, Vol. VI., 1883; Shallow-water Mollusca off Cape Hatteras, Report of the Commissioner of Fish and Fisheries for 1883, 1885; and Transactions of the Connecticut Academy, Vol. VI., 1885.

Dall, W. H. Report on Florida Shells, Proceedings of the U. S. National Museum, Vol. VI., 1883; Preliminary Report on the Mollusca obtained by the "Albatross" in 1887–88, Proceedings of the U. S. National Museum, Vol. XII., 1889; Marine Mollusks of the S. E. coast of the United States, Bulletin U. S. Nat. Mus., No. 37, 1889; Contributions to the Tertiary Fauna of Florida, Transactions of the Wagner Free Institute of Science of Philadelphia, Vol. III., 1890.

Pelseneer, P. Report of the "Challenger," Zoölogy (Heteropoda and Pteropoda), Vol. XXIII., 1888.

Sars, G. O. Mollusca Regionis Arcticæ Norvegiæ, 1878.

Verrill, A. E. Invertebrate Animals of Vineyard Sound, 1874; Results of the Explorations made by the Steamer "Albatross" in 1883, Report of the Commissioner of Fish and Fisheries for 1883, 1885.

Watson, R. B. Mollusca of the "Challenger" Expedition, Linnean Society's Journal, London, Vol. XV., 1881; Report of the "Challenger," Zoölogy, Vol. XV., 1886.

Whiteaves, J. F. Reports on the Deep-sea Dredgings in the Gulf of St. Lawrence, 1871–74.

LIST OF STATIONS FROM WHICH MOLLUSKS WERE RECEIVED.

Station No.	Locality. N. Lat.	W. Long.	Depth, Temperature, and Nature of Bottom. Fath.	F.°	Materials.	When collected.
	East of George's Bank.					
302	41° 30′ 0″	66° 0′ 0″	73	42.5	yl. S., bk. Spk., Sh.	1880
303	41 34 30	65 54 30	306	40.5	gy. S., bk. Spk., M.	"
304	41 35 0	65 57 30	139	44	No specimen.	"
305	41 35 15	65 51 25	810	39	dk.-gy. M., S., St.	"
306	41 32 50	65 55 0	524	39.5	" "	"
307	41 29 45	65 47 10	980	38	dk.-gy. M.	"
308	41 24 45	65 35 30	1,242	38	"	"
	South of George's Bank.					
309	40 11 40	68 22 0	304	40.5	dk.-gy. M., S.	"
	South of Martha's Vineyard.					
310	39 59 0	70 18 45	260	42	gn. M.	"
	Off Charleston, S. C.					
313	32 31 50	78 45 0	75	61.5	fne. gy. S., bk. Spk.	"
319	32 25 0	77 42 30	262	45.5	crl. S.	"
321	32 43 25	77 20 30	233	53.5	glb. O.	"
	Off Cape Fear, N. C.					
325	33 35 20	76 0 0	647	39	"	"
326	33 42 15	76 0 50	464	39.5	"	"
	Off Cape Lookout, N. C.					
329	34 39 40	75 14 40	603	39.75	"	"
	Off Cape Hatteras, N. C.					
330	35 41 3	74 31 0	1,047	38.5	glb. O., C.	"
331	35 44 40	74 40 20	898	39	glb. O.	"
332	35 45 30	74 48 0	263	41.5	"	"
333	35 45 25	74 50 30	65		Cl.	"
	Off Delaware Bay.					
334	38 20 30	73 26 40	395	41	glb. O., C.	"
336*	38 21 50	73 32 0	197	45	fne. gy. S., M.	"
337	38 20 8	73 23 20	740	39.5	glb. O.	"
338	38 18 40	73 18 10	922	39	"	"
339	38 16 45	73 10 30	1,186	39	"	"
	South of Martha's Vineyard.					
340	39 25 30	70 58 40	1,394	38	"	"
341	39 38 20	70 56 0	1,241	38	"	"
342	39 43 0	70 55 25	1,002	39	bl. C.	"
343	39 45 40	70 55 0	732	39.5	gn. S.	"
344	40 1 0	70 58 0	129	51	"	"
345	40 10 15	71 4 30	71	51	gn. M., brk. Sh., S.	"
346	40 25 35	71 10 30	43½	49	gn. M.	"
	Off Montauk Pt., L. I.					
347	40 59 0	71 22 30	24	60	crs. bl. S., yl. Spk.	"

CEPHALOPODA.

Argonauta argo Linné.

Verrill, Trans. Conn. Acad., V. pp. 364, 420, 1881; VI. pp. 247, 265, pl. 28, figs. 1, 1 *a*, 1 *b*, 1884.

Dall, Bulletin U. S. Nat. Mus., No. 37, pp. 174, 200, pl. 64, fig. 142 *b*; var. *americana*, pl. 43, figs. 1, 1 *a*, 1 *b*, and pl. 67, figs. 63, 63 *a*, 63 *b*, 1889.

A single fragment, Station 325, off Cape Hatteras, N. C., in 647 fathoms.

Several shells and many fragments have been taken by the U. S. Commission of Fish and Fisheries off the coast, from Martha's Vineyard to Chesapeake Bay, in 64 to 2,620 fathoms, and several living specimens at the surface.

Mr. Dall records this species as far south as the West Indies, and, doubtfully, from Brazil. He gives the varietal name *americana* to all found off our coast, because of their broader form and fewer radial folds and cardinal nodules.

In a series of perfect shells of moderate size, taken with the animal, I find marked variation in the prominence and number of the folds and nodules. Some of them could not be distinguished from authentic specimens of about the same size from Sicily, in the collection of the Peabody Museum of Yale University. It is only the large, full-grown specimens that seem to be narrow and more compressed in form.

GASTROPODA.

TOXOGLOSSA.

Pleurotoma (Drillia) Dalli Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 451, pl. 57, figs. 1, 1 *a*, 1882; VI. p. 265, 1884.
Drillia ? Dalli Dall, this Bulletin, XVIII. p. 92, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 98, pl. 60, fig. 66 *a*, 1889.

One living and one dead specimen, Station 345, south of Martha's Vineyard, in 71 fathoms.

A rare species, found by the U. S. Fish Commission off the coast, from Martha's Vineyard to Delaware Bay, in 94 to 188 fathoms; not living below 120 fathoms.

Two varieties of this species — *acloneta*, without transverse sculpture, and *cestrota*, with conspicuous sculpture — are recorded by Mr. Dall as found from Georgia to the West Indies, in 170 to 294 fathoms, dead.

Our specimens show marked variation in the development of the transverse sculpture, but there are none in which it is entirely wanting.

Pleurotoma (Drillia) amblytera, sp. nov.

Plate I. Figs. 5, 5 a.

Three living specimens and one dead, Station 313, off Charleston, S. C., in 75 fathoms.

Two living specimens were dredged by the U. S. Fish Commission in 1883, off Cape Hatteras, N. C., in 142 fathoms.

This species is closely related to the preceding, but has a stouter form, shorter and more rapidly tapered spire, ornamented with more conspicuous transverse ribs, with a narrower and less perceptible subsutural band, and a larger, more prominent apical whorl.

It also bears a superficial resemblance to *Drillia æpynota*, Dall (this Bulletin, XVIII. p. 96, pl. 36, fig. 10, 1889), but the fewer number of its whorls (the latter is described as having ten, yet the figure given shows only seven) and transverse ribs, with its more strongly marked striæ and conspicuous posterior sinus, will readily distinguish it.

The animal is drawn so far into the shell in all the specimens as to render the study of it impossible.

Shell consisting of eight whorls, rather thick, of a light yellow color, sometimes banded with reddish brown. The posterior sinus is nearly round, situated just below the suture, and has, in the best developed specimen, a thin, sharp edge rising a little above the surface of the shell, bending decidedly backward, then curving and nearly meeting in front. The outer lip rounds gradually to near the anterior end of the aperture, where it is slightly contracted, making a short, broad canal, then twisting abruptly backward produces a decided notch before joining the columella. A conspicuous varix is formed by the thickening of the last rib, beyond which the outer lip is thin, white, and sharp-edged. There is a prominent, tooth-like projection on the interior of the aperture, at the end of the varix, more conspicuous in some specimens than in others, and seen best in an end view. Interior of the aperture and inner lip white. Columella straight, with a conspicuous layer of enamel having a thin, free edge. Suture distinct, undulating. Subsutural band very narrow, concave, lapping well on the preceding whorl. Prominent, strong, oblique, rounded ribs, nine on the body whorl, separated by concave spaces of about the same width, cross the whorls from suture to suture, faintly defined on the subsutural band, and most prominent just below it. On the body whorl, these gradually fade away at the base of the siphon, and appear on the canal as conspicuous, much curved lines of growth. Microscopic striæ intersect the fine lines of growth, giving to the entire surface of the shell a peculiar crinkled appearance. Nucleus broad, blunt, smooth, somewhat shining, consisting of two and a half turns ; the apical whorl large, rising very little above the succeeding one.

Length of the largest specimen, 15 mm.; greatest breadth, 6 mm.; length of aperture, 6 mm.

Pleurotomella Agassizii Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 454, pl. 57, figs. 3, 3*a*; VI. p. 265, 1884.
Dall, this Bulletin, XVIII. p. 121, 1889.
Non Pleurotomella Sandersoni Dall, *loc. cit.*
Pleurotomella Agassizii Dall, Bulletin U. S. Nat. Mus., No. 37, p. 197, pl. 60, fig. 67, *non* figs. 71, 71*a*, 1889.
Pleurotomella Agassizii var. *mexicana* Dall, this Bulletin, XVIII p. 121, 1889.
? *Mangilia Agassizii* var. *mexicana* Dall, Bulletin U. S. Nat. Mus., No. 37, p. 180, pl. 11, fig. 14, 1889.
Pleurotomella Agassizii var. *permagna* Dall, Proc. U. S. Nat. Mus., XII. p. 308, 1889.

Two living specimens and one dead, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 325, off Cape Fear, N. C., in 647 fathoms. Three living (one young), Station 326, off Cape Fear, in 464 fathoms. One living and six dead (four young), Station 329, off Cape Lookout, N. C., in 603 fathoms. Two dead, Station 330, north of Cape Hatteras, N. C., in 1,047 fathoms. One living, Station 334, off Delaware Bay, in 395 fathoms. One living and two dead, Station 337, off Delaware Bay, in 740 fathoms. One living and one dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms. One living, Station 343, south of Martha's Vineyard, in 732 fathoms.

A common species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 39 to 1,608 fathoms, not living below 1,539 fathoms.

Extending south as far as Tobago, in 202 to 880 fathoms (Dall). Living in 841 fathoms.

Mr. Dall gives the varietal name *mexicana*[1] to specimens of this species found in the Gulf of Mexico, on account of their being of small size, white, with faint color on the columella. In the hundreds of specimens from Northern waters in the F. C. collection there is great variation in form, elegance of sculpture, and purity of color. To an elongated form he gives the varietal name of *permagna*. This is a quite common form among our specimens, although I have found none that reach a length of 47 mm. Their lengths range from 30 to 40 mm.

We have the perfect young of this species in all stages of development from 5 mm. on, and I have carefully compared them with a series of *Pleurotomella Sandersoni* Verrill,[2] but do not agree with Mr. Dall in combining the two species. The large, inflated body whorl, abruptly tapered spire, small nucleus, and the comparative smoothness of the surface, are characters which ought sufficiently to distinguish the young of *P. Agassizii* from the latter, which is slender, gradually tapered, with large nucleus, and very prominent though delicate sculpture.

[1] The figure quoted above was first published in this Bulletin, XVIII pl. 11, fig. 14, as *Mangilia ipara* Dall, p. 115. Mr. Dall does not state whether the change was intentional or not.

[2] Trans. Conn. Acad., VI. pp. 149, 266, pl. 31, figs. 3, 3*a*, 1884

Pleurotomella atypha, sp. nov.

Plate I. Fig. 3.

Two dead specimens, Station 325, in 647 fathoms, and one living specimen, Station 326, in 464 fathoms, off Cape Fear, N. C.

Shell rather large, solid, somewhat translucent, bluish white, with a comparatively smooth surface and little lustre. Spire unusually high, consisting of nine angularly shouldered whorls below the small, very acute, chestnut-brown nucleus. Aperture short, broad. Posterior sinus as broad as the subsutural band, rather shallow. Outer lip considerably inflated, curving gradually toward the columella without forming a decided canal. Columella nearly straight, curved slightly anteriorly, with a narrow, closely adhering strip of enamel. Suture distinct, undulating, slightly channelled. Subsutural band rather broad, oblique, somewhat concave, ornamented on the upper whorls with fine, distinct, curved riblets and lines of growth, the latter alone being visible on the two lower whorls. Just above the periphery, at the edge of the subsutural band, very narrow, sharp, slightly raised, oblique ribs, separated by very wide, slightly concave spaces, cross the whorls to the suture, and on the body whorl disappear just below the sutural line of the aperture. These ribs are most conspicuous at the shoulder, and vary considerably in different specimens, changing from the above narrow, sharp ones, with wide interspaces, to others broad and rounded, with narrower interspaces, the number on the body whorl varying from twelve to fifteen. The entire surface, except the nucleus and subsutural band, is cut by fine, shallow grooves separated by flattened spaces of unequal width ; these are deeper and coarser, or broader, on the lower part of the body whorl and canal, causing the spaces between them to appear as raised rounded threads. Nucleus long, very slender, consisting of four and a half finely reticulated light chestnut-brown whorls. The apical whorl is imperfect, but must have been very minute, judging from the size of the succeeding one.

Length of the largest specimen, destitute of the nucleus and one or two upper whorls, 30 mm. ; greatest breadth, 12 mm. ; length of aperture, 13.5 mm. ; its greatest breadth, 4 mm. A smaller specimen with a nearly perfect nucleus is 23.5 mm. long; about 8.5 mm. broad ; width of the last nuclear whorl, 0.5 mm.

This species resembles in general appearance the elongated form of *Pleurotomella Agassizii* V. & S., but is quite different in detail. The most apparent distinguishing characters are its high, finely pointed spire and nearly smooth surface.

It is perhaps closely related to the much smaller *Pleurotomella filifera* Dall (this Bulletin, IX. p. 56, 1881; XVIII. p. 123, pl. 12, fig. 9, 1889). The figure quoted was evidently made from a specimen with an imperfect nucleus, as it shows but seven whorls.

Pleurotomella Jeffreysii Verrill.

Trans. Conn. Acad., VI. p. 411, pl. 44, fig. 3, 1885.

Non Pleurotoma (Defrancia) chariessa Watson, Linn. Soc. Journ., London, XV. p. 458, 1881.

Non Clathurella chariessa Watson, Chall. Voyage, Zoölogy, XV. p. 352, pl. 20, fig. 6, 1886.

Pleurotomella chariessa Dall, Bulletin U. S. Nat. Mus., No. 37, p. 191, pl. 46, fig. 3, 1889; this Bulletin, XVIII. p. 122, 1889.

? *Pleurotomella chariessa* var. *pistillata* Dall, Trans. Wagner Free Inst., III. p. 41, 1890.

Two perfect, though dead specimens, Station 308, east of George's Bank, in 1,242 fathoms. A rare species, first dredged by the U. S. F. C. in 1884, ranging from east of George's Bank to Chesapeake Bay, in 984 to 2,620 fathoms; not living in less than 1,525 fathoms. Mr. Dall records it as far south as St. Vincent, in 464 to 966 fathoms, dead.

In the F. C. collection there is nearly a complete series of this species, ranging in length from 10 to 52 mm. Among these there is considerable variation in their proportionate lengths. Two specimens, having the same number of whorls and the same width, vary in height, one measuring 38 and the other 43 mm.

Mr. Dall gives the varietal names *spica*, *phalera*, *tellea*, and *aresta*, to various deviating forms of this species found off the Southern coast. I do not agree with him in identifying this with *Clathurella chariessa* of Watson. That species is described as being about 21 mm. in length, and consisting of 10 whorls in all, of which 4½ form the nucleus. It is also said to have 20 oblique, transverse ribs on the body whorl. A perfect living young example of our species, measuring about 20 mm. in length, has but 4 whorls beside the nucleus, and but 15 ribs on the body whorl.

The figure given by Mr. Watson is certainly quite different from Professor Verrill's, especially in the degree of angularity of the shoulder, obliquity of the transverse sculpture, and in the form of the body whorl and canal.

Pleurotomella sp.

A badly worn and broken specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

This shell bears a superficial resemblance to the young of *P. atypha*, with which it was at first combined, but after a careful study it proves to be quite different in detail. The other known species to which I notice its having any relation is *Leucosyrinx Sigsbeei* Dall (this Bulletin, XVIII. p. 76, pl. 11, fig. 10, 1889). It is impossible to decide definitely, without careful comparison of more perfect specimens.

It has a slender, elongated form, with obtusely shouldered whorls; wide, oblique subsutural band; a rather long, narrow aperture, ending in a decided

canal. The shoulder of the whorls, situated at the periphery, is ornamented with rather broad, slightly angular, oblong, oblique nodules, thirteen on the penultimate whorl, separated by slightly concave, about equally wide spaces. The entire surface, except the subsutural band, is covered by raised, rounded, revolving threads of nearly uniform size, which extend over the shoulder a little way on the subsutural band, where they are a little finer and closer together than elsewhere.

Length, 22 mm.; breadth, 8 mm.; length of aperture, 10 mm.

Pleurotomella sulcifera, sp. nov.

Plate II. Fig. 4.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell rather large, fusiform, rather thin, translucent white with very little lustre. It has a high, regularly tapered spire of six obtusely shouldered whorls, not counting the nucleus which is broken off, and a long, nearly straight columella and a broad, straight aperture occupying about half the length of the shell. Posterior sinus as broad as the subsutural band, shallow, slightly broken. Outer lip thin, curving very gently to join the columella with but a very slight bending in anteriorly, not forming a well-defined canal. Columella with a thin, narrow strip of enamel extending its entire length. Suture inconspicuous. Subsutural band rather broad, oblique, crossed by delicate slightly curved riblets, most distinct on the upper whorls. Narrow, oblique, angular ribs, fifteen on the body whorl, separated by rather deep, narrow spaces, cross the whorls, rising just above the periphery and not quite reaching to the suture; these are cut just above the middle by a broad, shallow groove, making them appear, especially on the body whorl, as two rows of nodules. In some positions of the shell there seems to be a second similar groove (scarcely discernible) below this one. The spiral sculpture is very irregular. On the body whorl, below the transverse ribs, there are from twenty-five to thirty shallow grooves, varying in width, and having between them flattened bands or threads. On the canal they are so close together that their interspaces appear like rounded threads; above these, about the middle of the whorl, they are very broad, and separated by equally broad flattened bands, while still above these, below the ribs, they are again narrowed and separated by flattened threads. On the ribs the grooves also vary considerably. On each side of the principal groove, a rather broad, flattened thread forms a slight crest on the summit of the ribs, and beyond the lower one of these there are two or three fine rounded threads. The principal groove is also interrupted by a rounded thread at about the middle, and two or three very faint ones above and below it. On the upper part of the ribs there are two or three unequal grooves. On the penultimate whorl there are four grooves below the principal one, separated by nearly equal spaces, with but a single rounded thread on the centre of the first or principal one. With the exception of the subsu-

tural band, the surface is covered with microscopic striæ, which, in intersecting the inconspicuous lines of growth, give a peculiar crinkled appearance to the surface.

Length, 30 mm.; breadth, 12 mm.; length of aperture, 15.5 mm.; greatest breadth, 5.5 mm.

This species is easily distinguished by the character of its sculpture.

Pleurotomella leptalea, sp. nov.

Plate II. Figs. 5, 5 a.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, rather stout, very thin and fragile, delicately tinted with brown below the chestnut-brown tip, consisting of four obtusely shouldered whorls besides the nucleus. Aperture long, rather broad, pinched in anteriorly, forming a moderately long, narrow canal. Outer lip badly broken, but, judging by the lines of growth, sweeps well forward from the posterior sinus, which is as wide as the subsutural band, and deepest next the suture. Columella very straight for this genus, with a narrow, very thin, closely adhering layer of enamel. Subsutural band broad, oblique, crossed by numerous very delicate curved riblets and lines of growth, most conspicuous just at the suture. At the angle of the shoulder just below the periphery there is, on the two upper whorls, a row of small nodules, which gradually disappear on the penultimate whorl and are entirely wanting on the last one. The spiral sculpture consists of narrow, shallow grooves separated by rather broad, flattened bands of nearly uniform width, which cover the entire surface except the subsutural band and nucleus. Those on the shoulder are a little closer together than elsewhere. Lines of growth rather indistinct. Nucleus large, consisting of four conspicuously reticulated, chestnut-brown whorls which increase in size very abruptly from the very small apical whorl.

Length, 12 mm.; breadth, 6 mm.; length of aperture, 7.5 mm.; greatest breadth, about 2.5 mm.

This species more closely resembles the young of *P. Emertoni* V. & S. (Trans. Conn. Acad., VI. p. 154, pl. 31, fig. 6, 1884) than any of the other known forms. It can, however, be readily distinguished by its more regularly coiled and less acute spire; less prominent transverse sculpture; and especially by the very different form of the aperture, which in *P. Emertoni* is very broad, without any clearly defined canal.

Pleurotomella Dalli, sp. nov.

Plate II. Figs. 2, 2 a.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, rather slender, thin, white, with a waxy lustre, consisting of nine regularly coiled whorls, having a broad oblique subsutural band

and prominent transverse nodules, and on the body whorl conspicuous widely separated spiral threads. Spire about half the length of the shell, acutely conical in outline, ornamented with prominent nodules just above the sutures, and with a shining, pale yellowish brown tip. Aperture narrow, oblique. Posterior sinus deep, as broad as the subsutural band. Outer lip thin, reaching far forward, curving in anteriorly, forming a short, narrow canal, and joining the columella in a regular curve without any notch. Columella very strongly curved with a thin, ill-defined layer of enamel. Suture defined by a fine rounded thread. Subsutural band, crossed only by the very conspicuous, strongly curved lines of growth intersected by indistinct microscopic striæ, reaches to the periphery of the whorls, where prominent, nearly straight, oblong, angular, transverse nodules, fifteen on the body whorl, rise very abruptly and terminate just above the suture, and are separated by spaces about equal to their own width. On the body whorl, below the nodules, there are twelve conspicuous, raised, rounded, widely separated threads. The space between them measures about 0.5 mm.; on the canal it decreases slightly, so that the last four or five threads are a little nearer together. The lines of growth are clearly defined and, under the microscope, are everywhere intersected by indistinct striæ. Minute microscopic granules are scattered over the entire surface, scarcely discernible on the nuclear whorls. Apical whorl small, smooth, slightly raised above the next whorl, which, with the succeeding turn, forms the nucleus. These are ornamented with a fine, distinct peripheral keel, which under the microscope is found to be divided into minute beads. There is no operculum. The animal is drawn so far into the shell as to render the study of it impossible.

Length, 11 mm.; breadth, 5 mm.; length of aperture, 5.5 mm.

This is a very beautiful species, and quite distinct from any known form.

Mangilia leuca, sp. nov.

Plate I. Fig. 2.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Shell rather large for the genus, regularly fusiform, thin, translucent, bluish white, with a roughened surface of waxy lustre, and a shining tip of a delicate yellow tint. Spire about half the length of the shell, of seven decidedly shouldered whorls, besides the nucleus. Aperture long and narrow. Posterior sinus large and nearly round, commencing at the suture and reaching to the shoulder, cutting into the top of the varix formed by the thickening of the last transverse rib, thus showing a thickened border with the upper edge rounded but not raised above the surface of the shell, extending farther back than the inner edge and curving strongly with the lines of growth, nearly meeting in front; from this the thin outer lip reaches far forward over the aperture, leaving a very narrow opening. Near the anterior end it is pinched in slightly, then bends abruptly backward as though cut off obliquely, revealing the entire

width of the canal, and, curving a little upward, forms a slight notch before joining the columella. The edge of the lip is rounded and crimped by the termination of the revolving threads. Columella with a slight sigmoid curvature and an inconspicuous layer of enamel. Suture distinct, undulating, slightly channelled. The concave subsutural band occupies about a third of the width of the upper whorls, and is crossed by fine indistinct lines of growth. Conspicuous, rather broad, angular, oblique ribs cross the whorls, scarcely evident on the subsutural band, but rise somewhat abruptly on its lower edge, forming a sharp shoulder at the periphery. There are eleven of these ribs on the body whorl, reaching to the base of the canal; these, with their equally broad, concave interspaces, are ornamented with about twenty-five conspicuously raised, uniform, rounded threads, pretty regularly separated, but a little crowded on the anterior end of the canal. On the penultimate whorl there are six of them, the first just above the shoulder and the last just above the suture. Lines of growth very indistinct. Nucleus small, shining, consisting of three and a half regularly coiled whorls, the lower one ornamented with a peripheral keel. The entire surface of the shell is covered with minute granules, closely crowded except on the nucleus, where they are somewhat scattered and discernible only under a high magnifying power.

Length, 15 mm.; breadth, about 6 mm.; length of aperture, about 7 mm.; breadth, about 2 mm.

I can find no description nor figure that bears any resemblance to this very elegant species.

Bela cancellata (Mighels) Stimpson.

Verrill, Trans. Conn. Acad., V. p. 475, pl. 43, figs. 10, 11; pl. 57, fig. 18, 1882.

One living specimen, Station 344, south of Martha's Vineyard, in 129 fathoms.

A Northern species recorded by the U. S. F. C. in small numbers from a comparatively few stations between Sable Island Bank and south of Martha's Vineyard, in 12½ to 547 fathoms; not living below 126 fathoms. It has also been recorded by Prof. Verrill from Eastport, Me., and by Prof. A. S. Packard from Labrador.

RHACHIGLOSSA.

Buccinum Sandersoni Verrill.

Trans. Conn. Acad., V. p. 490, pl. 58, fig. 9, 1882.

One living specimen, Station 306, east of George's Bank, in 524 fathoms. One dead, Station 309, south of George's Bank, in 304 fathoms.

A rare species recorded by the U. S. F. C. from off Martha's Vineyard, in 156 to 264 fathoms; not living in less than 208 fathoms.

Buccinum cyaneum Bruguière.

Verrill, Trans. Conn. Acad., V. p. 492, pl. 43, fig. 5; pl. 58, fig. 11, 1882.

One living specimen, Station 303, east of George's Bank, in 306 fathoms.

A common Northern species found by the U. S. F. C. from north of George's Bank to southeast of Martha's Vineyard, in 26 to 471 fathoms.

Buccinum abyssorum Verrill and Smith.

Verrill, Trans. Conn. Acad., VI. p. 167, pl. 31, figs. 11, 11 *b*, 1884.

Over fifty living specimens, Station 308, east of George's Bank, in 1,242 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883; ranging from east of George's Bank to off Cape Hatteras, N. C., in 49 to 1,434 fathoms; not living in less than 906 fathoms.

Sipho Stimpsonii Mörch.

Verrill, Trans. Conn. Acad., V. p. 499, pl. 57, fig. 24, 1882.

One living and five dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms. Four living, Station 332, off Cape Hatteras, N. C., in 263 fathoms. One living, young (var. *liratulus* V.), Station 344, south of Martha's Vineyard, in 129 fathoms.

Recorded by the U. S. F. C. from Misaine Bank to off Cape Hatteras, N. C., in 16 to 471 fathoms.

Sipho pubescens Verrill.

Trans. Conn. Acad., V. p. 501, pl. 43, fig. 6; pl. 57, fig. 25, 1882.

One dead specimen, Station 309, south of George's Bank, in 304 fathoms. Over twenty living specimens, Station 310, south of Martha's Vineyard, in 260 fathoms. Over twenty living and twelve dead, Station 329, off Cape Lookout, N. C., in 603 fathoms. One dead, Station 332, off Cape Hatteras, N. C., in 263 fathoms. One living, Station 334, off Delaware Bay, in 395 fathoms. Over twenty living, Station 336, off Delaware Bay, in 197 fathoms.

A very abundant species found by the U. S. F. C. from off Misaine Bank to off Cape Hatteras, N. C., in 42 to 677 fathoms; not living in less than 57 fathoms or below 640 fathoms.

Sipho pygmæus (Gould) Verrill.

Verrill, Trans. Conn. Acad., V. pp. 501 and 505 (note), pl. 57, fig. 21, 1882.

One living specimen, Station 303, east of George's Bank, in 306 fathoms. Three living specimens and one dead, Station 310, south of Martha's Vineyard,

in 260 fathoms. Over twenty-five living and dead, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Nine living, Station 336, off Delaware Bay, in 197 fathoms. Nine living and twelve dead, Station 344, south of Martha's Vineyard, in 129 fathoms. One living, Station 345, south of Martha's Vineyard, in 71 fathoms. Two living, Station 346, south of Martha's Vineyard, in 44 fathoms.

A common shallow-water species recorded by the U. S. F. C. from St. Peter's Bank to off Cape Hatteras, N. C., in 10 to 1,004 fathoms.

Sipho obesus Verrill.

Trans. Conn. Acad., VI. p. 168, 1884.

One living specimen, Station 331, off Cape Hatteras, N. C., in 898 fathoms. One living, Station 340, south of Martha's Vineyard, in 1,394 fathoms.

A rare species found by the U. S. F. C. from Martha's Vineyard to off Cape Hatteras, N. C., in 102 to 859 fathoms ; not living in less than 707 fathoms or below 843 fathoms.[1]

Mr. Dall gives Florida as the most Southern limit of range of this species.

Sipho cælatus Verrill.

Trans. Conn. Acad., V. p. 506, pl. 57, figs. 19, 19 *a*, 1882.

Five living and ten dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. Five living and four dead, Station 326, off Cape Fear, in 464 fathoms. Two living and four dead, Station 329, off Cape Lookout, N. C., in 603 fathoms. Five living, Station 334, off Delaware Bay, in 395 fathoms. Three living, Station 337, off Delaware Bay, in 740 fathoms. One dead, Station 343, south of Martha's Vineyard, in 732 fathoms.

Found in considerable numbers by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 75 to 1,537 fathoms; not living in less than 302 fathoms.

Sipho cælatus var. hebes Verrill.

Trans. Conn. Acad., VI. p. 172, 1884.

Five living and ten dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A few are recorded by the U. S. F. C. from east of George's Bank to off Chesapeake Bay, in 444 to 1,255 fathoms.

[1] One very young living specimen is recorded from the U. S. F. C. Station 2272, off Cape Hatteras, N. C., in 15 fathoms.

Sipho cælatulus Verrill.[1]

Trans. Conn. Acad., VI. p. 172, 1884.

Plate II. Fig. 1.

Two living specimens and one dead, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 307, east of George's Bank, in 980 fathoms. One living and three dead, Station 308, east of George's Bank, in 1,242 fathoms. Two dead, Station 339, off Delaware Bay, in 1,186 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms. One dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A common deep-water species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 326 to 1,356 fathoms.

Recorded by Mr. Dall, from off Jamaica, W. I., in 966 fathoms.

Neptunea despecta (Linné) Ad.

Verrill, Trans. Conn. Acad., V. p. 499, 1882.

One dead specimen, Station 309, southeast of Martha's Vineyard, in 304 fathoms.

A common, shallow-water, Northern species recorded by the U. S. F. C. from off St. Johns, Newfoundland, to south of Martha's Vineyard, in 34 to 471 fathoms; not living in less than 36 fathoms.

Murex (Pteronotus) pygmæus, sp. nov.

Plate I. Figs. 3, 4.

One living specimen, Station 319, off Charleston, S. C., in 262 fathoms.

Shell small, fusiform, rather thin, of a light yellow color. Whorls six, evenly and moderately rounded, ornamented with three high, thin foliaceous varices and covered with coarse revolving threads and microscopic striæ. Aperture nearly round, with a long, curved, tubular canal, and a smooth, lustrous interior. Outer lip with a slightly thickened edge, descending a little obliquely from the suture, forming a slight obtuse posterior angle, below which it is somewhat flaring and curves well round to the base of the canal, where there is another slight angle, then curves gradually outward to the end of the canal. Inner lip formed by a rather narrow, thin, lustrous layer of enamel closely adhering to the body whorl to just above the base of the canal, where it becomes detached and twists forward and over to meet the outer lip, nearly or quite

[1] Mr. Dall, in this Bulletin, XVIII. p. 174, 1889, suggests that this species is the same as *Sipho Bocagei* Fischer, but gives no reference to description or figure. In the limited number of Mr. Fischer's papers at my command, I have been unable to find such a species, and therefore can express no opinion on the subject.

closing the canal its entire length. There is a tube corresponding to a former canal on the left of the present one for about half its length, which projects strongly outward at the end. Operculum thin, horny, amber-colored. Suture distinct, slightly channelled. Varices three, equally spaced, high, very thin, with an irregular slightly notched edge, the last one formed a little before the edge of the outer lip. Each stands a little in front of the corresponding one above, rises above the suture, laps a little on to the preceding whorl, then reaches high above with a re-entrant curve, the greatest height being in a line with the posterior angle of the aperture. When dry, the surface on the back of these and between them is without lustre, and is covered with microscopic revolving striæ crossed by inconspicuous lines of growth. There are also a few broad, widely separated, rather indistinct revolving threads, which are most apparent on the varices. These number about eight on the last varix, but the two or three lowest ones are almost imperceptible. The surface on the front of the varices is very lustrous, covered with the very thin, irregular edges of the several layers of growth; the upper revolving threads appear as broad shallow grooves. Nucleus large, of two smooth lustrous whorls, the apical one prominent and decidedly upturned.

Length, 16 mm.; breadth, including varices, 9.5 mm.; length of aperture and canal, 10.5 mm.; of canal, 5.5 mm.; greatest height of the last varix, 3.5 mm.

This is a very interesting species and quite unlike any hitherto described.

Trophon Verrillii, sp. nov.

Plate I. Fig. 16.

Two living and three dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, thin, translucent, bluish white, slightly lustrous, consisting of five whorls besides the nucleus, with a rather high spire ornamented with numerous conspicuous lamellæ and revolving striæ, and a long, rather slender, nearly straight canal. Aperture very long, club-shaped. Outer lip thin, with the edge spreading outwards when forming a lamella, oblique above the shoulder, rendered slightly concave when there is a prominent spine on the shoulder, beyond which it is well rounded, curving abruptly in about the middle of the aperture, at the base of the canal, then continuing in a straight line, bending nearly at right angles to join the columella. Columella very decidedly twisted, curving outward from the point opposite the constriction of the outer lip, so that the canal is broad and open. Interior of the aperture very smooth and glassy. Suture distinct, undulating, slightly channelled. Conspicuous thin lamellæ cross the whorls, directed obliquely backwards from the suture to the periphery, below which they bend slightly forward, and on the body whorl continue to the end of the canal. The number varies from twelve to fourteen in different specimens. In some specimens these lamellæ rise into prominent

spines at the shoulder, directed decidedly upward, but in others they are scarcely perceptible. The entire surface is covered with microscopic revolving striæ, more distinct in some specimens than in others, crossing the obscure lines of growth. Nucleus large, smooth except for the microscopic striæ, shining, consisting of one and a half turns, with a large, rather prominent apical whorl.

Length of the largest specimen, which is broken at the tip, 18.5 mm.; breadth, 8.5 mm.; length of aperture, 11 mm.; its breadth, about 3.5 mm.; length of canal, about 6.5 mm. Length of a smaller, perfect specimen, 14.5 mm.; greatest breadth, about 7 mm.; length of aperture, 9 mm.; its breadth, 2.5 mm.; length of canal, about 4.5 mm.

Trophon clavatus Sars, *T. abyssorum* Verrill and its variety *limicola* Verrill, *T. aculeatus* Watson, and *Boreotrophon* (*aculeatus* Watson, var.?) *lacunellus* Dall, are all related to the present species.[1] A careful study of their descriptions and figures, however, reveals marked differences in their size, number of whorls, character and number of lamellæ, and presence or absence of spiral sculpture. *T. aculeatus* Watson is doubtless most readily distinguished by the distinct angulation or keel at the shoulder of the whorls.

Anachis Haliæeti (Jeffreys).

Anachis costulata Verrill, Trans. Conn. Acad., V. p. 513, pl. 43, fig. 7, 1882.
Anachis Haliæeti Verrill, *op. cit.*, VI. p. 252, 1884.
Dall, Bulletin U. S. Nat. Mus., No. 37, p. 116, 1889.

One living specimen, Station 310, south of Martha's Vineyard, in 260 fathoms. One living, Station 336, off Delaware Bay, in 197 fathoms.

Common in the U. S. F. C. collection from Cashe's Ledge to off Cape Hatteras, N. C., in 48 to 1,537 fathoms; not living in less than 52 fathoms.

Astyris diaphana Verrill.

Verrill, Trans. Conn. Acad., V. p. 513, pl. 58, fig. 2, 1882.
Dall, this Bulletin, XVIII. p. 191, pl. 35, fig. 9, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 118, pl. 35, fig. 9, 1889.

One living specimen, Station 321, off Charleston, S. C., in 233 fathoms.

A comparatively rare species found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 64 to 487 fathoms; not living in less than 100 fathoms. Mr. Dall records it as far south as the Gulf of Mexico, in 196 fathoms, dead.

[1] G. O. Sars, Moll. Reg. Arct. Norvegiæ, p. 249, pl. 15, fig. 12; pl. 23, fig. 14; pl. 9, fig. 17, 1878. Verrill, Trans. Conn. Acad., VI. p. 421, 1885. Watson, Chall. Voyage, Zoölogy, XV. p. 169, pl. 10, fig. 9, 1886. Dall, this Bulletin, XVIII. p. 205, pl. 15, fig. 4, 1889.

TÆNIOGLOSSA.

Natica clausa Brod. and Sowerby.

One living specimen, Station 303, east of George's Bank, in 306 fathoms.

Found by the U. S. F. C. in both shallow and deep water from off St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 16 to 1,537 fathoms. Found also by the Stearns Expedition on the coast of Labrador, in 1 to 8 fathoms.

Lunatia heros (Say) H. & A. Ad.

One living and five dead specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., from the shore to 238 fathoms. Also recorded, by Mr. J. F. Whiteaves, from the Gulf of St. Lawrence, and by Prof. A. S. Packard, from Labrador.

Lunatia Grönlandica (Möll.) Ad.

One dead specimen, Station 310, south of Martha's Vineyard, in 260 fathoms. Two dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. One living, Station 332, off Cape Hatteras, N. C., in 263 fathoms.

Found in both shallow and deep water by the U. S. F. C. from off Cape Race, Newfoundland, to off Cape Hatteras, N. C., in 8 to 1,356 fathoms. Also found by the Stearns Expedition on the coast of Labrador, in 3 to 8 fathoms.

Crucibulum striatum (Say) H. & A. Ad.

Fourteen living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms. One living, Station 347, off Montauk Point, L. I., in 24 fathoms.

A common shallow-water species found by the U. S. F. C. from the Bay of Fundy to off Cape Hatteras, N. C., from the shore to 231 fathoms; not living below 67 fathoms.

Recorded by Mr. Dall from off Sand Key, Florida, in 128 fathoms, dead.

Aporrhais occidentalis Beck.

One dead specimen, Station 309, south of George's Bank, in 304 fathoms. Nine dead specimens, Station 310, south of Martha's Vineyard, in 260 fathoms.

A very common species found by the U. S. F. C. from St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 20 to 1,000 fathoms ; not living below 349 fathoms. Recorded by Mr. J. F. Whiteaves, from the Gulf of St. Lawrence, and found by the Stearns Expedition on the coast of Labrador, in 2 to 20 fathoms.

GYMNOGLOSSA.

Turbonilla Rathbuni Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 536, pl. 58, fig. 15, 1882.

Three dead specimens, Station 310, south of Martha's Vineyard, in 260 fathoms.

A rare species found by the U. S. F. C. from off Martha's Vineyard to off Cape Hatteras, N. C., in 64 to 547 fathoms; not living in less than 100 fathoms or below 365 fathoms.

RHIPIDOGLOSSA.

Calliostoma occidentale (Migh.).

Three living specimens, Station 302, east of George's Bank, in 73 fathoms. One living, Station 307, east of George's Bank, in 980 fathoms. One living, Station 310, south of Martha's Vineyard, in 260 fathoms.

A Northern species found by the U. S. F. C. from northwest of Flemish Cap (Station 2697) to south of Martha's Vineyard, in 27 to 640 fathoms. Also found by Professor Verrill at Eastport, Me., and Grand Menan, N. B.

Calliostoma Bairdii Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 530, pl. 57, fig. 26, 1882.

Seven living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. from off Martha's Vineyard to off Cape Hatteras, N. C., in 43 to 640 fathoms; not living in less than 64 fathoms or below 192 fathoms. Also recorded by Mr. Dall from the coast of Florida, in 100 to 200 fathoms, dead.

Margarita (Solariella) Ottoi Philippi.

Margarita regalis Verrill, Amer. Journ. Sci., XX. p. 397, 1880; Proc. U. S. Nat. Mus., III. p. 378, 1880; Trans. Conn. Acad., V. p. 530, pl. 57, fig. 37, 1882; VI. p. 254, pl. 29, fig. 14, 1884.
Solariella Ottoi Dall, this Bulletin, XVIII. p. 381, 1889.

One living specimen, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 306, east of George's Bank, in 524 fathoms. One living

and two dead, Station 307, east of George's Bank, in 980 fathoms. One dead, Station 343, south of Martha's Vineyard, in 732 fathoms.

Recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 63 to 1,594 fathoms; not living in less than 193 fathoms; and by Mr. Dall as far south as Grenada, in 416 fathoms, dead.

Mr. Dall has been able to decide definitely, by the comparison of authentic specimens, the question suggested by Mr. Jeffreys in 1883, as to whether the recent and fossil forms were not identical; but I notice that, in his more recent report on the "Albatross" mollusks (Proc. U. S. Nat. Mus., XII. p. 352, 1889), he retains *regalis* as a varietal name.

Margarita (Solariella) infundibulum Watson, var. Diomedeæ Verrill, nov.

Trochus (*Margarita*) *infundibulum* Watson, Journ. Linn. Soc., London, XIV. p. 707, 1879; Chall. Voyage, Zoölogy, XV. p. 84, pl. 5, fig. 5, 1885.

Solariella infundibulum Dall, this Bulletin, XVIII. p. 380, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 164, 1889; Proc. U. S. Nat. Mus., XII. p. 349, pl. 9, fig. 3, 1889 (Anatomy).

Plate II. Figs. 10 and 11.

One living specimen, Station 303, east of George's Bank, in 1,242 fathoms. One living, Station 340, south of Martha's Vineyard, in 1,394 fathoms.

A rare and beautiful deep-water species first dredged by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 679 to 1,782 fathoms.

Mr. Dall extends the range as far south as Brazil, in 769 to 860 fathoms, dead.

This variety differs from the typical form described by Mr. Watson chiefly in having two, and sometimes three, sharply tuberculated carinæ on all the whorls except those of the nucleus, and also in having on the base four nearly equally spaced, finely crenulated carinæ, besides a fifth which defines the umbilicus and is more strongly crenulated than the others; in some specimens it is sharply tuberculated.

Professor Verrill has kindly permitted me to give the following description, which was prepared by him from specimens in the collection of the U. S. F. C., but has not as yet been published: —

"Shell white, iridescent, large for the genus, with an elevated conical spire, consisting of about eight whorls, which are well rounded and ornamented with two (rarely three) tuberculated carinæ. Suture rather deep, sometimes slightly chanelled. Base convex and swollen, with a large umbilicus and ornamented with five (rarely six) prominent spiral lines or carinæ, which are usually separated by concave interspaces of nearly equal breadth; when there are six carinæ the interspaces become unequal. The outermost carina coincides

with the posterior edge of the lip ; the innermost one forms the border of the umbilicus, and is usually surmounted by a series of small, blunt tubercles formed by the crossing of the lines of growth; the outer three or four carinæ are usually more or less distinctly crenulated where they are crossed by the lines of growth, which are very distinct, and have the form of raised, rounded ridges in the interspaces, and increase in prominence toward the umbilicus. Above the line of the suture on the lower whorls there are two, or sometimes three, prominent revolving carinæ, which are regularly covered with prominent, subacute tubercles or denticulations, which vary considerably in number, prominence, and thickness. In the more common form, with the larger tubercles, there are on the body whorl about twenty-five to thirty tubercles on each carina, in other specimens forty, and in one case there are as many as sixty very small ones. The interspaces are broad, flattened, or even concave when the carinæ are very prominent. The whole surface is usually crossed by numerous oblique, distinctly raised, unequal lines of growth, of which the more prominent, in crossing the carinæ, form the tubercles. On the upper whorls the lines of growth are less distinct than on the lower, and sometimes scarcely obvious except close to the carinæ ; in such specimens the middle of the interspaces is nearly smooth and iridescent. The nucleus is prominent, the apical whorl being slightly upturned, rounded, smooth and white ; the second and third whorls are crossed by raised transverse ribs, and the revolving carinæ become distinct on the third whorl. The umbilicus is large, deep funnel-shaped, showing the volutions, bordered by a distinctly tuberculated carina, and covered, on the inner surface, by very regular and prominent sharp lines of growth, which become crowded within. Aperture nearly round, except where slightly notched beneath the carinæ; columella lip slightly excurved over the upper part of the umbilicus. In fresh specimens the surface is sometimes partially covered by a very thin, brownish yellow epidermis, which easily peels off, leaving the shell beautifully iridescent ; inner surface pearly white. Operculum circular, thin, pale yellow.

" Height, 22 mm.; breadth, 19 mm. Another specimen measures, in height, 21 mm. ; breadth, 19.5 mm."

Ganesa sp.

VERRILL, Trans. Conn. Acad., VI. p. 201, 1884.

One dead specimen, Station 307, east of George's Bank, in 980 fathoms.

Puncturella sp.

A very much worn and broken specimen, Station 321, off Charleston, S. C., in 233 fathoms.

Although so imperfect, this specimen is of interest in being the only one of this genus in the collection, and also in being quite distinct from *P. noachina*.

It is rather low and broad, with the posterior slope slightly oblique, the beak prominent, curving well over, with about two smooth whorls standing out on the right side. The anterior slope is convex, with a long and rather broad, partly closed slit tapered to a narrow point at the upper end, and reaching well up on the beak. The sculpture consists of radiating, well rounded, alternately larger and smaller ribs, crossed and rendered somewhat nodulose by rather regular concentric lines or threads. Interior smooth, with plain margin.

HETEROPODA.

Atlanta Peronii Les.

Verrill, Trans. Conn. Acad., V. p. 529, 1882; VI. pl. 28, figs. 4, 4 *a*, 1884.

A fragment, Station 325, off Cape Fear, N. C., in 647 fathoms.

A not uncommon pelagic species recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 1,825 fathoms; living at the surface.

Extending south to Bermuda (Dall).

TECTIBRANCHIATA.

Scaphander nobilis Verrill.

Trans. Conn. Acad., VI. p. 209, pl. 32, figs. 18–18 *d*, 1884.

Two living and three dead specimens, Station 308, east of George's Bank, in 1,242 fathoms.

A rare deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Delaware Bay, in 705 to 1,742 fathoms; not living below 1,434 fathoms.

Mr. Dall records this species from the Gulf of Mexico and off Tobago, in 880 and 1,639 fathoms, dead.

Scaphander puncto-striatus (Migh.) Ad.

Three living specimens and one dead (young), Station 303, east of George's Bank, in 306 fathoms. One dead, Station 305, east of George's Bank, in 810 fathoms. One living, Station 306, east of George's Bank, in 524 fathoms. Three dead (two young), Station 308, east of George's Bank, in 1,242 fathoms. One dead, Station 309, south of George's Bank, in 304 fathoms. Two living, Station 310, south of Martha's Vineyard, in 260 fathoms. Four dead (one young), Station 331, off Cape Hatteras, N. C., in 898 fathoms. Two living, Station

332, off Cape Hatteras, in 263 fathoms. Eighteen living and three dead (young), Station 336, off Delaware Bay, in 197 fathoms. One living, Station 338, off Delaware Bay, in 922 fathoms. One dead (young), Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A very abundant species found by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 11 to 1,467 fathoms; not living below 1,356 fathoms.

Mr. Dall extends the range south to the Barbados, in 288 to 533 fathoms, dead.

Cylichna vortex Dall.

Utriculus (?) *vortex* Dall, this Bulletin, IX. p. 100, 1881; XVIII. p 47, pl. 17, fig. 3, 1889.

Non Cylichna (?) *Dalli* Verrill, Trans. Conn. Acad., V. p. 542, 1882; VI. p. 274, pl. 29, fig. 15, 1884.

One dead specimen, Station 305, east of George's Bank, in 810 fathoms. One living, Station 307, east of George's Bank, in 980 fathoms.

Found by the U. S. F. C. from east of George's Bank to off Chesapeake Bay, in 326 to 1,356 fathoms; not living in less than 984 fathoms, or below 1,290 fathoms.

In studying the specimens labelled *Cylichna Dalli* in the F. C. collection I found some confusion in the identification, and that two similar but distinct forms had been placed under that name: *Cylichna Dalli* Verrill and *Cylichna vortex* Dall.

The differences in the two species are clearly shown in the figures quoted above. *C. Dalli* is most readily distinguished by its "strongly excavated and sinuous" columella, which forms anteriorly a distinct fold or tooth-like projection where it joins the strongly curved outer lip; while *C. vortex* has a gently curved columella, passing "imperceptibly" into the outer lip without "twist or fold."

In this species the apical whorl is smooth, upturned, and sunken in a shallow pit formed by the two succeeding whorls, one rising a little above the other, with a slightly rounded sutural margin. In some specimens these are so closely coiled as nearly to conceal the nucleus, while in others each turn is visible. The following turns are more loosely coiled, and the outer lip joins the body whorl a little below the apex of the shell.

Some of the F. C. specimens are considerably larger than Mr. Dall's types, and more slender in proportion to their length.

One perfect specimen is $16\frac{1}{2}$ mm. long and 8 mm. broad; another worn and broken one is about 29 mm. long and 13 mm. broad; while still another is 23 mm. long and 11 mm. broad.

A careful study of the radula and gizzard shows that the correct position of the species is with the *Cylichnæ*.

The radula consists of a series of strongly hooked, dark amber teeth, the lateral ones with broad curved bases and the marginal ones with simple straight bases, arranged in rows of five or seven on each side of the minute median tooth. In small specimens these hooks are distinctly roughened on the under surface by fine, raised, longitudinal lines. The three plates of the gizzard are club-shaped, with a yellow-white flattened exterior surface and a dark reddish brown convex interior surface, the greatest convexity situated beyond the middle, in the broader end, with a little flattened space in front defined by a lighter shade of color.

Diaphana (?) Lottæ, sp. nov.

Plate II. Figs. 8 and 9.

One dead specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Shell rather large, short and stout, abruptly tapered at the ends, truncate at the top with the two whorls of the spire showing in a shallow pit; translucent, yellowish white, with a slightly lustrous surface covered with distinct punctate spiral lines. The outer lip rises considerably above the level of the body whorl, arches well forward, and follows the curvature of the body whorl to near the base, where it is a little expanded, and joins the columella in a broad curve. The inner lip is formed by a rather wide, closely adhering layer of enamel, which is considerably thickened on the columella, spreading out over the umbilical region with a thick, free outer edge. The spiral lines are distinct and rather coarsely punctate, a little crowded on the apex of the shell, nearly uniformly separated to just below the centre (five to the millimeter), where there are two quite fine, widely separated ones, below which they become again coarser and considerably crowded on the base. Epidermis thin, very slightly tinged with yellow. Lines of growth inconspicuous.

Length of shell, 8 mm.; breadth, 5.5 mm.; length of aperture, 8.5 mm.

A smaller, somewhat worn specimen (No. 45,604), differing from the above only in having fewer spiral lines, was dredged by the U. S. F. C. in 1882, at Station 1142, off Martha's Vineyard, in 322 fathoms.

This species bears considerable resemblance to *Cylichna occulta* Migh. & Ad.; but that is a much smaller and more slender species, more gradually tapered toward the ends, with finer and more numerous spiral lines.

This species is named in honor of Miss Charlotte E. Bush, who has rendered valuable assistance in assorting and tabulating the specimens in this collection.

SCAPHOPODA.

Dentalium solidum VERRILL.

VERRILL, Trans. Conn. Acad., VI. p. 215, 1884, pl. 44, figs. 16, 17, 1885.

Three living specimens, Station 305, east of George's Bank, in 810 fathoms. Eight dead (seven young), Station 307, east of George's Bank, in 980 fathoms. One living and ten dead, Station 308, east of George's Bank, in 1,242 fathoms. One young, dead, Station 325, off Cape Fear, N. C., in 647 fathoms. One living, Station 331, off Cape Hatteras, N. C., in 898 fathoms. Three living, Station 338, off Delaware Bay, in 922 fathoms. Four living and one dead, Station 339, off Delaware Bay, in 1,186 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms. Four living and one dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 662 to 1,825 fathoms. Mr. Dall also records it from off the coast of Brazil, in 1,019 fathoms, dead.

It is with considerable hesitation that I retain the name *solidum* for this species, as Mr. Dall states,[1] with much positiveness, that our species is identical with Mr. Jeffreys's types of *Dentalium candidum*. But the descriptions and figures of the two species are so markedly different in their principal characters, that I cannot accept the identification without question.

Our specimens are large (about 3 inches long), robust, thick, and strong, with numerous, very distinct lines of growth, and, toward the posterior half, with marked, but shallow, longitudinal striations, or small impressed grooves, separated by slightly convex spaces, varying in width, and have the anterior aperture large, circular, moderately oblique, with plain, thin, sharp edge, and the posterior one small, pear-shaped, with a rather deep notch on the dorsal side, and a shallower, more rounded one beneath (all of which characters seem to be constant even in the perfect young). If specimens labelled *D. candidum* in the Jeffreys collection are like these, I do not see how they can agree with the description given by Mr. Jeffreys in Ann. Mag. Nat. Hist., p. 153, 1877, or with the figure in Proc. Zoöl. Soc., London, pl. 49, fig. 2, 1882, which agrees well with the description, especially in the character of the longitudinal sculpture. Mr. Jeffreys states that his species is thin, opaque, about 1.75 inches long, with about forty fine and regular rounded longitudinal striæ (I should judge from the figure that he must have meant threads or ribs) disappearing towards the front margin, crossed by extremely numerous microscopic circular lines. The anterior end broad and jagged; the posterior abruptly truncated, without notch, groove, slit, or channel.

[1] *Dentalium candidum* Dall, this Bulletin, XVIII. p. 422, 1889; Proc. U. S. Nat. Mus., XII. p. 294, 1889.

Mr. Dall's statement, that, judging from the figure, one would not anticipate the two species being identical, leads me to think that there may possibly have been some confusion in the labelling of the specimens, or there may be two species under the same name.

Dentalium occidentale, var. *sulcatum* Verrill (Trans. Conn. Acad., VI. p. 217, 1884) resembles, as already stated by Professor Verrill, the descriptions and figure of *D. candidum*.

Dentalium striolatum Stimp.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A very abundant species found by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 6 to 1,255 fathoms; not living in less than 35 fathoms.

Dentalium occidentale Stimp.

Verrill, Trans. Conn. Acad., V. pl. 42, figs. 16–18, 1882.

Nine living and seven dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms. Four living, Station 336, off Delaware Bay, in 197 fathoms.

An abundant species found by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., in 26 to 1,356 fathoms; not living in less than 51 fathoms. Recorded by Mr. J. F. Whiteaves from the Gulf of St. Lawrence.

Siphodentalium vitreum M. Sars?

Verrill, Trans. Conn. Acad., V. p. 557, pl. 42, fig. 19, 1882.

One dead specimen, Station 325. off Cape Fear, N. C., in 647 fathoms.

A very rare species found by the U. S. F. C. from south of Martha's Vineyard to Chesapeake Bay, in 368 to 811 fathoms; not living below 368 fathoms. Also recorded by Mr. J. F. Whiteaves from the Gulf of St. Lawrence.

The above specimen has been broken and evidently repaired by the animal, so that it is somewhat distorted, and does not agree perfectly with authentic specimens of this species from the north.

PTEROPODA.

Cavolina tridentata (Forskäl).

Verrill, Trans. Conn. Acad., V. p. 554, figs. 6, 7, 1882.

One dead specimen, Station 303, east of George's Bank, in 306 fathoms. One dead, Station 308, east of George's Bank, in 1,242 fathoms. A fragment, Station 321, off Charleston, S. C., in 233 fathoms. Four dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. One dead, Station 336, off Cape Fear, N. C., in 464 fathoms. One dead, Station 329, off Cape Lookout, N. C., in 603

fathoms. One dead, Station 340, south of Martha's Vineyard, in 1,394 fathoms. One dead, Station 344, south of Martha's Vineyard, in 129 fathoms.

An abundant pelagic species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Cavolina uncinata (Rang).

Verrill, Trans. Conn. Acad., V. p. 554, 1882.

Two dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. One dead, Station 325, off Cape Fear, N. C., in 647 fathoms.

A common pelagic species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 1,859 fathoms; living at the surface.

Extending south to Brazil.

Cavolina longirostris Les.

Verrill, Trans. Conn. Acad., V. p. 555, 1882.

One dead specimen, Station 321, off Charleston, S. C., in 233 fathoms.

A very abundant pelagic species recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 15 to 2,574 fathoms; living at the surface.

Extending south to Brazil.

Cavolina gibbosa (Rang).

Verrill, Trans. Conn. Acad., VI. p. 213, 1884.

Two dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms.

A rare pelagic species recorded by the U. S. F. C. from south of George's Bank to off Cape Hatteras, N. C. Dead shells in 193 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Diacria trispinosa (Les.).

Verrill, Trans. Conn. Acad., VI. p. 275, 1884.

Three dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. Two dead, Station 325, off Cape Fear, N. C., in 647 fathoms. Two dead, Station 326, off Cape Fear, in 464 fathoms.

A common pelagic species recorded by the U. S. F. C. from Sable Island Bank to off Cape Hatteras, N. C. Dead shells in 15 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Clio pyramidata Linné.

Verrill, Trans. Conn. Acad., V. p. 555, 1882.

Four dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. Two dead, Station 325, off Cape Fear, N. C., in 647 fathoms.

A rather common pelagic species recorded by the U. S. F. C. from off Nova Scotia to off Cape Hatteras, N. C. Dead shells in 16 to 2,033 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

LAMELLIBRANCHIATA.

Cuspidaria glacialis (Sars) Dall.

Neæra glacialis Verrill, Trans. Conn. Acad., V. p. 562, pl. 44, fig. 10, *a*, *b*, 1882.
Cuspidaria glacialis Dall, this Bulletin, XII. pp. 294, 303, 1886; XVIII. p. 444, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 66, 1889.

One living specimen, Station 310, southeast of Martha's Vineyard, in 260 fathoms. Seven living, and five valves, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Nine large living and four dead specimens, Station 336, off Delaware Bay, in 197 fathoms. Two living, Station 344, south of Martha's Vineyard, in 129 fathoms.

A common species found by the U. S. F. C. from west of St. Peter's Bank to off Chesapeake Bay, in 6 to 828 fathoms; not living below 568 fathoms. Also dredged in the Bay of Fundy.

Mr. Dall extends the range south to the Gulf of Mexico, in 1,467 fathoms; dead.

Cardiomya sp.[1]

A single left valve, Station 321, off Charleston, S. C., in 233 fathoms.

This specimen is badly broken, but shows an oblique, inflated form, with a very short, ill-defined, upturned rostrum, and a nearly smooth, slightly lustrous surface. On the posterior end there are several rather inconspicuous angular ribs. Two principal ones diverge from the beak to the margin. The upper one defines the rostrum, and has above it three fine, little raised radiating lines, which commence about half-way down from the beak and reach to the end of the rostrum. The second or lower rib has two or three shorter ones above and below it, which commence, as the lines on the rostrum, half-way down from the beak, and extend to the margin, which they make a little fluted. These ribs appear as shallow grooves on the interior of the valve. The rest of the surface is crossed only by indistinct, unequal lines of growth.

Length, 9 mm; height, 7 mm.

[1] Dall, this Bulletin, XII. p. 296, 1886.

This species, which is quite distinct from any of our Northern forms, seems to be most nearly related to *Cardiomya costellata* Deshayes[1]; but is too imperfect to identify with certainty.

Myonera paucistriata Dall.

Dall, this Bulletin, XII. p. 302, 1886; XVIII. p. 445, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 68, 1889; Proc. U. S. Nat. Mus., XII. p. 283, pl. 13, fig. 12, 1889.
Non Neæra paucistriata Bush, Trans. Conn. Acad., VI. p. 473, 1885.

Plate II. Fig. 18.

A badly smashed but living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Recorded by Mr. Dall as ranging from off Cape Fear, N. C., to off Tobago, in 193 to 880 fathoms; living in 339 to 464 fathoms.

I regret having to call attention to the inaccuracy in the synonymy of this species. Specimens from shallow water off Cape Hatteras, N. C., were forwarded to me from Washington under the manuscript name of *Neæra paucistriata* Dall, which name I accepted for my paper, quoted above, without question. The true *Myonera paucistriata* proves to be a quite different species.

The shallow-water species is small, with an oblique, inflated form, and a well developed, upturned, gaping rostrum. It is ornamented on the posterior half with three or four conspicuous, divergent, radiating ribs, and a few faint riblets, crossed by numerous concentric undulations, which are most clearly defined on the anterior half of both valves. It should be placed under the subgenus *Cardiomya*, and may possibly be the *C. costellata* of Deshayes, recorded by Mr. Dall from the same locality.

Periploma abyssorum Verrill (?)

Plate II. Figs. 12 and 13.

The broken left valve[2] of a young specimen, Station 332, off Cape Hatteras, N. C., in 263 fathoms.

A very large, new, and rare species recorded by the U. S. F. C. from east of Banquereau to off Chesapeake Bay, in 101 to 1,255 fathoms; not living in less than 906 fathoms.

Professor Verrill has kindly permitted me to give the following description, which was prepared by him from specimens dredged by the U. S. F. C., but has not as yet been published: —

"Shell large, broad, rather depressed, thin and delicate, but not very translucent, nearly equivalved, gaping somewhat posteriorly, the posterior end being bent a little to the right. The beaks are considerably behind the middle,

[1] Dall, this Bulletin, XII. p. 297.

[2] This fragment is hardly worthy of mention, but in the characters which are preserved agrees fairly well with the young of the above mentioned species in the F. C. collection.

acute, and turned directly inward, with a long, narrow ligamental furrow on the posterior side, which on the inner surface extends far inward in a transverse direction, as a narrow dark brown groove with a raised margin on each side. The antero-dorsal margin is a little convex, and broadly arched anteriorly, with a wave-like inbending of the margin below corresponding to a broad shallow depression extending from the umbos to the edge. The ventral margin is very broadly and evenly rounded, separated from the posterior region by a distinct, wave-like incurvature, corresponding to a double furrow running from the posterior side of the beak to the margin. The posterior region is a little prolonged and subtruncate at the end. The postero-dorsal margin slopes from the beak and is nearly straight, joining the posterior margin in a rounded angle.

"The cartilarge pit is moderately large, thick and strong, spoon-shaped or ovate, and curved obliquely backward, with the cartilage area in the form of a wedge-shaped depression; the plate is supported by a broad, thin rib, which runs from its inner surface inward and somewhat backward for a considerable distance; another much smaller rib runs from its posterior surface backward to the margin, leaving a triangular cavity between it and the principal rib. The pallial sinus is moderately large and deep, extending directly backward from the posterior tip, tapering and terminating in a bluntly rounded end. The inner surface, somewhat pearly and slightly concentrically waved, is also marked with rather indistinct radiating lines. The external surface is covered with rather conspicuous and narrow, unequal, concentric grooves and lines of growth; anteriorly there is a broad shallow transverse undulation, while posteriorly a narrow shallow depression, defined by two distinct furrows, curves from the beak to the posterior ventral margin; farther back a small, distinctly raised ridge extends from the posterior side of the beak to the posterior end; the area between this and the dorsal margin is covered by numerous fine radiating lines, not distinctly visible without a lens. The epidermis is thin and closely adherent, with irregular, raised, fibrous, concentric lines in some parts, especially on the posterior area.

"Length, 40 mm.; height from ventral margin to beak, 31 mm.; breadth, 16 mm.; length from beak to anterior end, 23 mm.; to posterior end, 15 mm.; length of cartilage plate, 3 mm.; length of internal rib, 9 mm.; its greatest breadth, 2 mm.; length of pallial sinus, 18 mm.; its breadth in middle, 8 mm."

Periploma fragilis (Totten).

Anatina papyratia Totten, Am. Journ. Sci., XXVIII. p. 347, pl. fig. 1, *a*, *b*, *c*, *d*, 1835.
Periploma fragilis Conrad, Am. Journ. Conch., II. p. 106, 1866.
Anatina papyracea Gould, Invert. Mass., Binney's ed., p. 66, fig. 382, 1870.
Periploma papyracea Verrill, Invert. Anim. Vineyard Sd., p. 379, pl. 27, fig 197, 1874; Trans. Conn. Acad., VI. p. 277, 1884.
Periploma fragilis Dall, this Bulletin, XII. p. 306, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 64, pl. 59, fig. 7, 1889.

Nine living specimens and two valves, Station 344, south of Martha's Vineyard, in 129 fathoms.

A rather common shallow-water species, rare in deep water, recorded by the U. S. F. C. from Eastport, Me., to off Delaware Bay, in 5 to 321 fathoms. Also found by the Stearns Expedition on the coast of Labrador, in 10 to 15 fathoms, and recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall as far south as the West Indies ; bathymetrical range not given.

Mr. Dall, in his recent report, calls attention to the fact that the true *P. papyracea* Say is quite distinct from the Northern form described by Mr. Totten, and given the provisional name *Anatina fragilis*.

Abra æqualis Say.

Verrill, Trans. Conn. Acad., V. p. 568, 1882.

A somewhat worn left valve, Station 321, off Charleston, S. C., in 233 fathoms.

Recorded from Stonington, Conn., in the stomachs of cod (Linsley).

A Southern species, detached valves of which are recorded by the U. S. F. C. from off Cape Hatteras, N. C., in 13 to 48 fathoms ; and one living specimen in 14 fathoms. Recorded by Mr. Dall as far south as the Gulf of Mexico ; bathymetrical range not given.

Macoma sabulosa (Speng.) Mörch.

One living specimen, Station 310, south of Martha's Vineyard, in 260 fathoms.

A common species found by the U. S. F. C. from off St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 6 to 1,255 fathoms ; by Prof. A. S. Packard and the Stearns Expedition on the coast of Labrador, in 1 to 15 fathoms; and by Mr. Dall on the coast of Florida as *M. proxima ;* bathymetrical range not given.

Cyprina Islandica (Linné) Lam.

One living specimen, Station 347, off Montauk Point, L. I., in 24 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and off Nova Scotia, to off Cape Hatteras, N. C., in 7 to 264 fathoms ; not living below 128 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Astarte undata Gld.

One valve, Station 303, east of George's Bank, in 306 fathoms. Six living and eight dead specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

A very common species found by the U. S. F. C. from the Bay of Fundy to off Cape Hatteras, N. C., in 7 to 480 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Astarte crenata Gray.

Astarte crebricostata Gould, Invert. Mass., Binney's ed., p. 126, fig. 440, 1870.
Astarte lens Verrill, Am. Journ. Sci., III. p. 287, 1872.
Astarte crenata Verrill, Proceed. U. S. Nat. Mus., III. p. 399, 1880.
Astarte lens Dall, Bulletin U. S. Nat. Mus., No. 37, p. 46, 1889.

Two dead specimens, Station 303, east of George's Bank, in 306 fathoms. One dead, Station 304, east of George's Bank, in 139 fathoms. Four living and one dead, Station 306, east of George's Bank, in 524 fathoms. Three living, Station 309, south of George's Bank, in 304 fathoms. Fifty living, Station 310, south of Martha's Vineyard, in 260 fathoms. One dead, Station 321, off Charleston, S. C., in 233 fathoms. One dead, Station 333, off Cape Hatteras, N. C., in 65 fathoms. One valve, Station 343, south of Martha's Vineyard, in 732 fathoms. Two valves, Station 344, south of Martha's Vineyard, in 129 fathoms. Three living, Station 345, south of Martha's Vineyard, in 71 fathoms.

A very common species found by the U. S. F. C. from northwest of Flemish Cap to off Cape Hatteras, N. C., in 7 to 677 fathoms; not living below 640 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall as far south as Cape Florida.

Venericardia granulata Say.

Verrill, Trans. Conn. Acad., VI. p. 258, 1884.

Three valves, Station 345, south of Martha's Vineyard, in 129 fathoms. Two living, Station 347, off Montauk Point, L. I., in 24 fathoms.

A very common species found by the U. S. F. C. from off Cape Race, Newfoundland, to off Cape Hatteras, N. C., in 7 to 435 fathoms; not living below 250 fathoms. Found by the Stearns Expedition on the coast of Labrador, in 10 fathoms.

Loripes lens Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 569, 1882; VI. p. 259, 1884.

Nineteen living and fourteen dead specimens, Station 344, south of Martha's Vineyard, in 129 fathoms. Three dead and one valve, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. off Cape Cod and Martha's Vineyard, in 5 to 231 fathoms; not living in less than 58 fathoms, or below 190 fathoms.

Extending south to Grenada, in 321 to 464 fathoms; living in 321 fathoms (Dall).

Lucina Blakeana, sp. nov.

Plate II. Figs. 16, 17.

One living specimen was found at Station 326, off Cape Fear, N. C., in 464 fathoms.

Shell of moderate size, a little longer than high, moderately convex, with a well-marked posterior undulation, rather thin, translucent white under a conspicuous light yellow epidermis. Umbos white, central, prominent, smooth near the beaks, which are small, pointed, curved strongly forward. Lunule long, rather broad, lanceolate, smooth, well excavated, so that the anterior dorsal margin is straight and slopes obliquely from the beaks. From this the margin rises slightly, curves well forward, forming a prominent, well-rounded anterior end before joining the broadly and regularly rounded ventral margin. Posterior dorsal margin long, sloping, nearly straight, forming a rounded angle where it meets the posterior ventral margin, which is distinctly incurved, corresponding to a slight but well-marked furrow extending from the umbos. The ligamental area is wide, sunken, tapering regularly towards either end, with a conspicuous ligament extending half its length. The surface is covered by irregular concentric lines and ridges, which, on the umbos, are nearly uniform in size and about equally separated, but below become very irregular and are covered with a thin light yellow epidermis decidedly wrinkled by the conspicuous lines of growth, most evident on the ends of the valves; in the centre it forms several (six in the type specimen) conspicuous, distant lamelliform ridges, the last one very near the edge. Interior bluish white, slightly lustrous, with numerous microscopic radiating striæ, most clearly defined near the margin, and a conspicuous concentric ridge situated half-way between the margin and the pallial line. Scars clearly defined. Hinge plate rather broad and well arched, with two prominent divergent, curved, cardinal teeth in the right valve, and a single thick, equally prominent one in the left valve. The anterior tooth in the right valve is more than twice as thick as the posterior, and has a well-marked central groove; the posterior one is situated directly beneath the beak, and is thin, curved, with the concave surface forward and the summit broadly rounded; the tooth in the left valve is about equal in size to the anterior one in the opposite valve, and also has a rather deep, central groove.

Length, 31 mm.; height, 27.5 mm.; thickness, about 13.5 mm.

This species has been carefully compared with authentic specimens of *L. filosa*, *borealis*, *Pennsylvanicus*, and *Jamaicensis*, but is quite distinct from all of them. It is readily distinguished by the irregular concentric sculpture, conspicuous epidermis, large lunule, long, broad, nearly straight ligamental area, and conspicuous ligament.

Cryptodon sp.

A broken left valve, Station 326, off Cape Fear, N. C., in 464 fathoms.

Although only a fragment, this differs so decidedly in form and sculpture from any of the species known to me, that it seems worthy of description. Its outline is much more angular than that of *C. ovoideus* Dall from the same locality.[1]

The ventral margin is too badly broken to judge of its outline, but the upper part of the valve is entire and shows an exceedingly high, narrow, angular, inflated form, with a small though prominent umbo and very sloping dorsal margins. Beak small, curved well forward over an exceedingly small, slightly sunken lunule, bordered by an inconspicuous ridge. The postero-dorsal margin is very long, straight (though strongly concave in an end view), and sloping, and is four and a half times the length of the lunular area. A single very deep narrow groove extends across the valve from the beak to the posterior ventral margin. In front and back of this there is a scarcely discernible undulation of the surface, and another equally slight one just back of the lunular ridge. Umbo nearly smooth and lustrous; the rest of the surface is roughened by the conspicuous, strongly curved lines of growth. Color, yellowish white. Interior bluish white, with a slightly lustrous frosted surface, which, under the microscope, appears covered with minute shallow pits. The exterior groove forms a conspicuous interior ridge. The ligamental groove is rather narrow, straight, sunken, running nearly the entire length of the postero-dorsal margin. At the end of the ligament, just beneath the beak, there is a prominent angular tooth-like process.

Length of lunular area, 2 mm.; of posterior dorsal margin, 9 mm.

Diplodonta turgida Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 569, pl. 58, fig. 42, 1882; VI. pl. 30, figs. 10, 11, 1884.

Fragments, Station 345, south of Martha's Vineyard, in 71 fathoms.

A rare species, only disunited valves of which have been found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 27 to 167 fathoms.

A single valve, off Grenada, in 170 fathoms (Dall).

Yoldia thraciformis (Storer) Stimp.

Five dead specimens and one valve, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Twenty living and four dead, Station 336, off Delaware Bay, in 197 fathoms.

A common species recorded by the U. S. F. C. from the Bay of Fundy and west of St. Peter's Bank to off Cape Hatteras, N. C., in 16 to 906 fathoms; and by Mr. Whiteaves from the Gulf of St. Lawrence.

[1] *Cryptodon ovoideus* Dall, Proc. U. S. Nat. Mus., XII. p. 263 (no description), pl. 14, fig. 3, 1889.

Yoldia sapotilla (Gould) Stimp.

Over fifty living specimens, Station 344, south of Martha's Vineyard, in 129 fathoms. Six living and three dead, Station 345, south of Martha's Vineyard, in 71 fathoms. Four living and two valves, Station 346, south of Martha's Vineyard, in 44 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and west of St. Peter's Bank to off Martha's Vineyard, in 4½ to 1,054 fathoms; not living in less than 8 fathoms, or below 428 fathoms. Also recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Professor Packard from Labrador.

Yoldia lucida Lovén.

Leda lucida Jeffreys, Brit. Conch., V. p. 173, pl. 100, fig. 1, 1869.
Yoldia obesa Gould, Invert. Mass, Binney's ed., p. 155, fig 463, 1870.
Verrill, Invert. Anim. Vineyard Sd., p. 396, 1874.
Portlandia lucida Sars, Moll. Reg. Arct. Norveg., p. 37, pl. 4, figs. 8 *a*, 8 *b*, 1878.
Leda lucida Jeffreys, Proc. Zoöl. Soc., London, p. 578, 1879.
Yoldia lucida Verrill, Trans. Conn. Acad., V. pl. 44, fig. 1, 1882.

One living specimen, Station 305, east of George's Bank, in 810 fathoms.

A small species found in considerable numbers by the U. S. F. C. from the Bay of Fundy and northwest of Flemish Cap to off Cape Hatteras, N. C., in 22 to 2,620 fathoms.

Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Yoldia callista, sp. nov.

Plate I. Figs. 9 and 10.

One living specimen, Station 321, off Charleston, S. C., in 233 fathoms.

This is a very small species, with a smooth, shining surface, covered with very fine microscopic lines of growth. It is narrow, nearly regularly ovate in outline, with small beaks, curved well forward, and situated at about the anterior third. Exteriorly the shell resembles a minute *Callista*. The anterior dorsal margin is somewhat concave, the posterior decidedly convex; while the ends are narrowed and nearly evenly rounded to meet the regularly curved ventral margin. Epidermis wanting. The interior has also a very shining surface with plain margins. The hinge margin is rather wide and thin, with six distinct well-separated teeth before and nine behind the beak. Cartilage pit minute, triangular, situated directly below the beak.

Length, 2.5 mm.; height, about 2 mm.

This species bears considerable resemblance to the young of *Y. regularis*, described by Professor Verrill (Trans. Conn. Acad., VI. p. 228, 1884), but the latter is very much broader and more oval in outline, with broadly rounded ends and the dorsal margins evenly convex. The most striking differences are

in the smaller number of teeth, and in the size and position of the cartilage pit, which in *Y. regularis* is very large, and situated a considerable distance behind the beak.

Leda quadrangularis Dall.

This Bulletin, XII. p. 253, pl. 8, fig. 6, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 42, pl. 8, fig. 6, 1889.

A single right valve, Station 321, off Charleston, S. C., in 233 fathoms.

This specimen is broken away on the posterior ventral margin, but in general outline agrees well with Mr. Dall's figure. There is, however, a marked difference in the number of teeth; besides the principal ones, six before and eight behind the beak, as mentioned by Mr. Dall, there are four minute ones on either side of an exceedingly narrow (microscopic) smooth space (not a pit) directly beneath the beak. The hinge margin is also remarkably wide and strong in my specimen.

From Cape Hatteras, N. C., to Cuba, in 683 to 1,568 fathoms, dead (Dall).

Leda acuta Conrad.

Leda unca, Verrill, Trans. Conn. Acad., V. p. 572, pl. 58, fig. 41, 1882.
Leda acuta Verrill, *op. cit.*, VI. p. 259, pl. 30, fig. 15, 1884.
Dall, this Bulletin, XII. p. 251, pl. 7, figs. 3 *a*, 3 *b*, 8, 1886; XVIII p. 438, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 44, pl. 7, figs. 3, 8; pl. 45, fig 15; pl. 64, fig. 140, 1889.

One living, Station 345, south of Martha's Vineyard, in 71 fathoms.

Found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 43 to 225 fathoms; not living in less than 63 fathoms, or below 155 fathoms.

Also recorded by Mr. Dall as far south as the West Indies, in 54 to 80 fathoms, dead.

Leda pernula (Müll.).

Verrill, Trans Conn. Acad., V. p. 572, 1882; VI. p. 280, pl. 30, figs. 14, 14 *a*, 1884.

One living, Station 331, off Cape Hatteras, N. C., in 898 fathoms.

A rare species found by the U. S. F. C. from off Cape Race, Newfoundland, to off Chesapeake Bay, in 25 to 479 fathoms.

Malletia obtusa (M. Sars) Mörch.

Verrill, Trans. Conn. Acad., VI. p. 226, 1884.

Three valves, Station 307, east of George's Bank, in 980 fathoms. Fragments, Station 325, off Cape Fear, N. C., in 647 fathoms. Two valves, Station 340, south of Martha's Vineyard, in 1,394 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 516 to 1,781 fathoms; not living in less than 525 fathoms.

Arca pectunculoides Sc.

VERRILL, Trans. Conn. Acad., V. p. 573, pl. 44, fig. 6, 1882.
DALL, this Bulletin, IX. p. 121, 1881; XII. p. 240, pl. 8, fig. 5, 1886; Bulletin U. S. Nat Mus., No. 37, p. 42, pl. 8, fig. 5, 1889.

Twelve living specimens (six very large), Station 310, south of Martha's Vineyard, in 260 fathoms. Seven valves, Station 321, off Charleston, S. C., in 233 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and northwest of Flemish Cap to off Chesapeake Bay, in 11 to 965 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall from St. Vincent, in 292 to 1,568 fathoms; living in 292 fathoms.

Macrodon asperula DALL?

This Bulletin, IX. p. 120, 1881; XII. p. 244, pl. 8, figs. 4, 4 *a*, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 42, pl. 8, figs. 4, 4 *a*, 1889.

A right valve, Station 321, off Charleston, S. C., in 233 fathoms.

The valve is very badly worn, and, although agreeing very closely with Mr. Dall's description and figures, is referred to this species with some doubt.

Extending south to the West Indies, in 310 to 1,568 fathoms, dead (Dall).

Limopsis minuta (PHIL.).

VERRILL, Trans. Conn. Acad., V. p. 576, 1882.

Plate I. Fig. 8.

One dead specimen, Station 307, east of George's Bank, in 980 fathoms. Seven living specimens, Station 310, south of Martha's Vineyard, in 260 fathoms. Two valves, Station 321, off Charleston, S. C., in 233 fathoms.

A very common species found by the U. S. F. C. from the east end of Banquereau to off Cape Hatteras, N. C., in 64 to 2,221 fathoms; not living in less than 155 fathoms.

Extending south to Grenada, in 30 to 850 fathoms; living in 30 fathoms (Dall).

Pecten Clintonius SAY.

VERRILL, Trans. Conn. Acad., VI. p. 261, 1884.

One valve, Station 333, off Cape Hatteras, N. C., in 65 fathoms. Five living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms. One

living, Station 346, south of Martha's Vineyard, in 44 fathoms. Three living (one large and two small), Station 347, off Montauk Point, L. I., in 24 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and St. Peter's Bank to off Cape Hatteras, N. C., in 7 to 813 fathoms; not living in less than 9 fathoms, nor below 146 fathoms. Recorded by Prof. A. S. Packard from the coast of Labrador.

Pecten vitreus (Gmel.) Wood.

Verrill, Trans. Conn. Acad., V. p. 581, pl. 42, fig. 21, 1882.

Twenty living specimens, Station 306, east of George's Bank, in 524 fathoms. Three living, Station 307, east of George's Bank, in 980 fathoms. Thirteen living, Station 309, south of George's Bank, in 304 fathoms. Two valves, station 310, south of Martha's Vineyard, in 260 fathoms. One living, Station 336, off Delaware Bay, in 197 fathoms.

An abundant species found by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., in 57½ to 1,537 fathoms; not living in less than 100 fathoms.

Amusium (Propeamusium) Pourtalesianum, var. striatulum Dall.

Dall, this Bulletin, XII. p. 212, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 34, 1889.
Amusium lucidum, var. *striata* Jeffreys, Proc. Zoöl. Soc. London, p. 562, 1879.

A fragment, Station 321, off Charleston, S. C., in 233 fathoms.

Extending south to St. Vincent, in 138 to 424 fathoms, dead (Dall).

This is a fragment of a very delicate shell, having a lustrous interior surface and about ten internal ribs, which terminate in rounded points or knobs a considerable distance within the margin, and are distinctly visible on the exterior surface, which is also lustrous and covered with microscopic concentric lines, and, on the upper half of the valve, with slight radiating striæ.

In these characters it seems to agree with Mr. Jeffreys's description of *A. lucidum*, var. *striata*, but, according to Mr. Dall's enumeration of specimens, should receive the name as given above.

Limæa subovata (Jeff.) Monteros.

Verrill, Trans. Conn. Acad., V. p. 580, 1882.

One valve, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A common deep-water species recorded by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 45 to 1,362 fathoms; not living below 1,290 fathoms.

Anomia aculeata Müll.

One living specimen, Station 345, south of Martha's Vineyard, in 71 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and Flemish Cap to off Cape Hatteras, N. C., in 4 to 640 fathoms ; Stearns Expedition, on the coast of Labrador, in 8 to 15 fathoms.

MOLLUSCOIDEA.

BRACHIOPODA.

Terebratulina septentrionalis (Couth.).

One living specimen and one valve, Station 310, south of Martha's Vineyard, in 260 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and St. Peter's Bank to south of Martha's Vineyard, in 7 to 1,081 fathoms ; not living below 677 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Atretia gnomon Jeff.

Verrill, Trans. Conn. Acad., VI. p. 445, 1885.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Found by the U. S. F. C. in 1884, off Martha's Vineyard and Delaware Bay, in 1,525 to 1,594 fathoms.

Extending south to Florida Straits ; bathymetrical range not given (Dall).

LIST OF SPECIES

ENUMERATED IN THE PRECEDING PAPER.[1]

The species in Italics are additions to the fauna of the Atlantic coast. Those with *s* before them are Southern species; those with an asterisk, Northern species which range as far south as Cape Hatteras, N. C.; and those with a dagger, Northern species which reach farther south.

CEPHALOPODA.

*Ommastrephes illecebrosus (Les.) V.
†Mastigoteuthis Agassizii V.
Chiroteuthis Bonplandi D'Orb. (?)
†Rossia sublevis V.
†Heteroteuthis tenera V.
†Argonauta argo Linné.
†Octopus Bairdii V.
*s*Octopus lentus V.
Octopus sp.
Eledone verrucosa V.

GASTROPODA.

Toxoglossa.

†Pleurotoma Dalli V. & S.
s Pleurotoma amblytera Bush.
†Pleurotomella Agassizii V. & S.
s Pleurotomella atypha Bush.
†Pleurotomella Jeffreysii V.
s Pleurotomella sp.
s Pleurotomella sulcifera Bush.
s Pleurotomella leptalea Bush.
s Pleurotomella Dalli Bush.
s Mangilia leuca Bush.
Bela cancellata (Migh.) Stimp.

Rhachiglossa.

Buccinum Sandersoni V.
Buccinum cyaneum Brug.
*Buccinum abyssorum V. & S.
†Sipho Stimpsonii Mörch.
†Sipho pubescens V.
*Sipho pygmæus (Gld.) V.
†Sipho obesus V.
*Sipho cælatulus V.
†Sipho cælatus V.
†Sipho cælatus, var. hebes V.
Neptunea despecta (Linné) Ad.
s Murex (*Pteronotus*) *pygmæus* Bush.
s Trophon Verrillii Bush.
*Anachis Haliæeti (Jeff.).
†Astyris diaphana V.

Tænioglossa.

*Natica clausa Brod. & Sower.
*Lunatia heros (Say) H. & A. Ad.
†Lunatia Grönlandica (Möll.) Ad.
†Crucibulum striatum (Say) H. & A. Ad.
*Aporrhais occidentalis Beck.

Gymnoglossa.

*Turbonilla Rathbuni V. & S.

Rhipidoglossa.

Calliostoma occidentale (Migh.).
†Calliostoma Bairdii V. & S.
†Margarita (Solariella) Ottoi Phil.
†*Margarita* (*Solariella*) *infundibulum* Watson, var. *Diomedeæ* V.
Ganesa sp.
s Puncturella sp.

[1] With the exception of the Cephalopods, which were taken, with Professor Verrill's permission, from his report on the "Blake Cephalopods," published in this Bulletin, Vol. VIII., 1881.

HETEROPODA.

†Atlanta Peronii Les.

TECTIBRANCHIATA.

†Scaphander nobilis V.
†Scaphander puncto-striatus (Migh.) Ad.

SCAPHOPODA.

†Dentalium solidum V.
†Dentalium striolatum Stimp.
†Dentalium occidentale Stimp.
†Siphodentalium vitreum M. Sars.?

PTEROPODA.

†Cavolina tridentata (Forskäl).
†Cavolina uncinata (Rang).
†Cavolina longirostris Les.
†Cavolina gibbosa (Rang).
†Diacria trispinosa (Les.).
†Clio pyramidata Linné.

LAMELLIBRANCHIATA.

†Cuspidaria glacialis (Sars) Dall.
s*Cardiomya* sp.
sMyonera paucistriata Dall.
**Periploma abyssorum* V. (?)
†Periploma fragilis Totten.
sAbra æqualis Say.
†Macoma sabulosa (Speng.) Mörch.
*Cyprina Islandica (Linné) Lam.
*Astarte undata Gld.
†Astarte crenata Gray.
*Venericardia granulata Say.
†Loripes lens V. & S.
s*Lucina Blakeana* Bush.
s*Cryptodon* sp.
†Diplodonta turgida V. & S.
*Yoldia thraciformis (Storer) Stimp.
Yoldia sapotilla (Gld.) Stimp.
*Yoldia lucida Lovén.
s*Yoldia callista* Bush.
sLeda quadrangularis Dall.
†Leda acuta Conrad.
*Leda pernula (Müll.).
†Malletia obtusa (M. Sars) Mörch.
sMacrodon asperula Dall.
†Arca pectunculoides Sc.
†Limopsis minuta (Phil.).
*Pecten Clintonius Say.
*Pecten vitreus (Gmel.) Wood.
sAmusium (Propeamusium) Pourtalesianum, var. striatulum Dall.
†Limæa subovata (Jeff.) Mont.
*Anomia aculeata Müll.

MOLLUSCOIDEA.

BRACHIOPODA.

Terebratulina septentrionalis (Couth.). †Atretia gnomon Jeff.

REFERENCES TO DESCRIPTIONS AND NOTICES OF ADDITIONAL SPECIES FIGURED ON THE ACCOMPANYING PLATES.

Adeorbis supranitidus Wood, var. *Orbignyi* Fischer, Dall, this Bulletin, XVIII. p. 278, 1889.
Astyris pura Verrill, Trans. Conn. Acad., V. p. 515, 1882.
Cingula Sandersoni Verrill, *op. cit.*, VI. p. 241, 1885.
Cocculina reticulata Verrill, *op. cit.*, p. 426.
Limopsis plana Verrill, *op. cit.*, p. 441.
Mangilia eritima Bush, Trans. Conn. Acad., VI. p. 456.
Mangilia quadrata Reeve, var. *quadrata* Dall, *op. cit.*, p. 113.
Marginella aureocincta Stearns, Proc. Bost. Soc. Nat. Hist., XV. p. 22, 1873; Dall, *op. cit.*, p. 139.
Marginella Smithii Verrill, *op. cit.*, pp. 420, 452.
Nucula trigona Verrill, *op. cit.*, p. 438. (Name preoccupied.)
Nucula Verrillii Dall, *op. cit.*, p. 248; Proc. U. S. Nat. Mus., XII. p. 257, pl. 14, fig. 4, 1889.
Pandora Carolinensis Bush, *op. cit.*, p. 474.
Scala leptalea Bush, *op. cit.*, p. 465; Dall, *op. cit.*, p. 309. (*Scalaria* preoccupied.)
Skenea lirata Verrill, *op. cit.*, V. p. 529, 1882; VI. p. 452, 1885.
Trophon abyssorum Verrill, and var. *limicola* Verrill, *op. cit.*, p. 421.

PEABODY MUSEUM OF YALE UNIVERSITY.

INDEX.

The names in Italics are those which are synonyms, or cited for comparison, or not included in the body of this work.

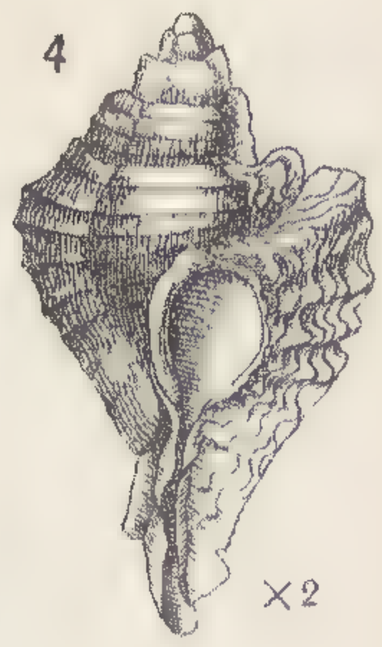
Abra æqualis, 229, 239.
Adeorbis supranitidus, var. *Orbignyi*, 240.
Amusium lucidum, var. *striata*, 236.
(Propeamusium) Pourtalesianum, var. striatulum, 236, 239.
Anachis costulata, 215.
Haliæeti, 215, 238.
Anatina fragilis, 229.
papyracea, 228.
papyratia, 228.
Anomia aculeata, 237, 239.
Aporrhais occidentalis, 216, 238.
Arca pectunculoides, 235, 239.
Argonauta argo, 202, 238.
var. *americana*, 202.
Astarte crebricostata, 230.
crenata, 230, 239.
lens, 230.
undata, 229, 239.
Astyris diaphana, 215, 238.
pura, 240.
Atlanta Peronii, 220, 239.
Atretia gnomon, 237, 239.
Bela cancellata, 210, 238.
Boreotrophon aculeatus, var. 215.
lacunellus, 215.
Buccinum abyssorum, 211, 238.
cyaneum, 211, 238.
Sandersoni, 210, 238.
Calliostoma Bairdii, 217, 238.
occidentale, 217, 238.
Cardiomya sp., 226, 239.
costellata, 227.
Cavolina gibbosa, 225, 239.
longirostris, 225, 239.
tridentata, 224, 239.
uncinata, 225, 239.
Chiroteuthis Bonplandi, 238.
Cingula Sandersoni, 240.
Clathurella chariessa, 206.
Clio pyramidata, 226, 239.
Cocculina reticulata, 240.
Crucibulum striatum, 216, 238.
Cryptodon sp., 232, 239.
ovoideus, 232.
Cuspidaria glacialis, 226, 239.
Cylichna (?) *Dalli*, 221.
occulta, 222.
vortex, 221, 239.
Cyprina Islandica, 229, 239.
Dentalium candidum, 223, 224.
occidentale, 224, 239.
var. *sulcatum*, 224.
solidum, 223, 239.
striolatum, 224, 239.
Diacria trispinosa, 225, 239.
Diaphana (?) Lottæ, 222, 239.
Diplodonta turgida, 232, 239.
Drillia æpynota, 203.
amblytera, 203, 238.
Dalli, 202, 238.
Eledone verrucosa, 238.
Ganesa sp., 219, 238.
Heteroteuthis tenera, 238.
Leda acuta, 234, 239.
lucida, 233.
pernula, 234, 239.
quadrangularis, 234, 239.
unca, 234.
Leucosyrinx Sigsbeei, 206.
Limæa subovata, 236, 239.
Limopsis minuta, 235, 239.
plana, 240.
Loripes lens, 230, 239.
Lucina Blakeana, 231, 239.
borealis, 231.
filosa, 231.
Jamaicensis, 231.

Lucina Pennsylvanicus, 231.
Lunatia Grönlandica, 216, 238.
heros, 216, 238.
Macoma proxima, 229.
sabulosa, 229, 239.
Macrodon asperula, 235, 239.
Malletia obtusa, 234, 239.
Mangilia Agassizii, 204.
var. *mexicana*, 204.
eritima, 240.
ipara, 204.
leuca, 209, 238.
quadrata, var. *quadrata*, 240.
Margarita (Solariella) infundibulum, var.
Diomedeæ, 218, 238.
Ottoi, 217, 238.
regalis, 217.
Marginella aureocincta, 240.
Smithii, 240.
Mastigoteuthis Agassizii, 238.
Murex (Pteronotus) pygmæus, 213, 238.
Myonera paucistriata, 227, 239.
Natica clausa, 216, 238.
Neæra glacialis, 226.
paucistriata, 227.
Neptunea despecta, 213, 238.
Nucula trigona, 240.
Verrillii, 240.
Octopus sp., 238.
Bairdii, 238.
lentus, 238.
Ommastrephes illecebrosus, 238.
Pandora Carolinensis, 240.
Pecten Clintonius, 235, 239.
vitreus, 236, 239.
Periploma abyssorum, 227, 239.
fragilis, 228, 239.
papyracea, 228.
Pleurotoma amblytera, 203, 238.
Dalli, 202, 238.
var. *acloneta*, 202.
var. *cestrota*, 202.
Pleurotomella sp., 206, 238.
Agassizii, 204, 238.
var. *mexicana*, 204.
var. *permagna*, 204.
Pleurotomella atypha, 205, 238.
chariessa, 206.
var. *pistillata*, 206.
Dalli, 208, 238.
Emertoni, 208.
filifera, 205.
Jeffreysii, 206, 238.
leptalea, 208, 238.
Sandersoni, 204.
sulcifera, 207, 238.
Portlandica lucida, 233.
Puncturella sp., 219, 238.
noachina, 219.
Rossia sublevis, 238.
Scala leptalea, 240.
Scaphander nobilis, 220, 239.
puncto-striatus, 220, 239.
Sipho *Bocagei*, 213.
cælatulus, 213, 238.
cælatus, 212, 238.
var. hebes, 212, 238.
obesus, 212, 238.
pubescens, 211, 238.
pygmæus, 211, 238.
Stimpsonii, 211, 238.
Siphodentalium vitreum, 224, 239.
Skenea lirata, 240.
Solariella infundibulum, 218.
Ottoi, 217.
var. *regalis*, 218.
Terebratulina septentrionalis, 237, 239.
Trochus (*Margarita*) *infundibulum*, 218.
Trophon *abyssorum*, 215, 240.
var. *limicola*, 215, 240.
aculeatus, 215.
clavatus, 215.
Verrillii, 214, 238.
Turbonilla Rathbuni, 217, 238.
Utriculus (?) *vortex*, 221.
Venericardia granulata, 230, 239.
Yoldia callista, 233, 239.
lucida, 233, 239.
obesa, 233, 239.
regularis, 233, 239.
sapotilla, 233, 239.
thraciformis, 232, 239.

1
×6

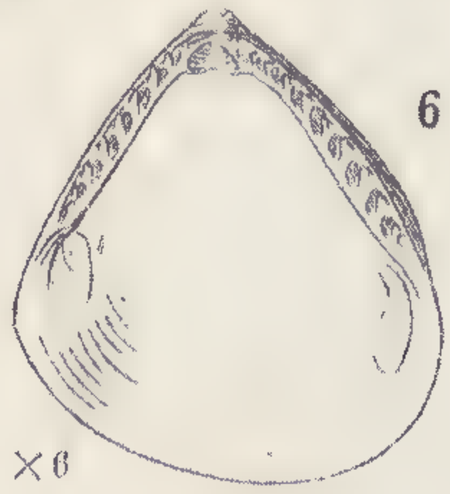
2
×3

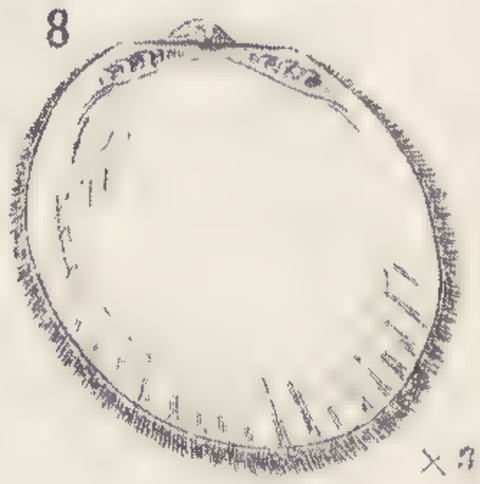
3
×2


4
×2

5
×2

5a
×2


6
×6


8
×3

14
×3

7
×6

9
×12

16
×2

15
×3

13
×6

10
×12

11
×12

17
×8

18
×9

19
×9

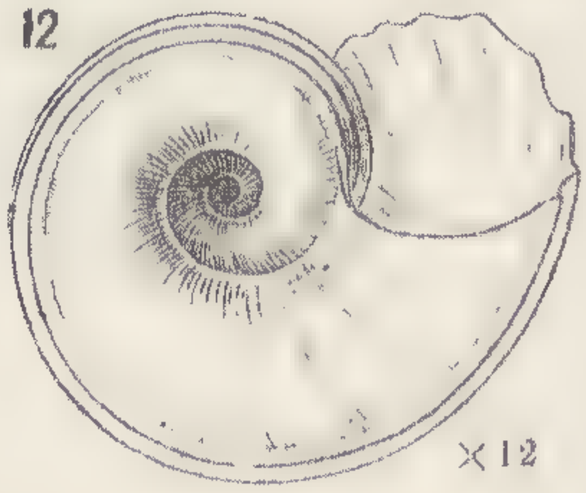

12
×12

Photo. Lith. by L. S. Punderson, New Haven

EXPLANATION OF PLATES.

I am indebted to Prof. A. E. Verrill for permission to use in these plates some of the drawings prepared from specimens in the collection of the U. S. National Museum, by Mr. J. H. Blake.

PLATE I.

Fig. 1. *Mangilia eritima* Bush (*Mangilia quadrata* Reeve, var. *quadrata* Dall). Front view; × 6 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2280, in 16 fathoms, 1884. Page 240.

Fig. 2. *Mangilia leuca* Bush. Front view; × 3 diameters. Nucleus and outer lip broken. Page 209.

Fig. 3. *Murex* (*Pteronotus*) *pygmæus* Bush. Dorsal view; × about 2 diameters. Page 213.

Fig. 4. The same. Front view; × about 2 diameters.

Fig. 5. *Pleurotoma* (*Drillia*) *amblytera* Bush. Front view; × about 2 diameters. Page 203.

Fig. 5*a*. The same. Side view of the body whorl; × about 2 diameters.

Fig. 6. *Nucula Verrillii* Dall (*Nucula trigona* Verrill). Interior view; × 6 diameters. Off Chesapeake Bay, U. S. F. C. Station 2229, in 1,423 fathoms, 1884. Page 240.

Fig. 7. The same. Exterior view; × 6 diameters.

Fig. 8. *Limopsis minuta* (Phil.). Interior view; × 3 diameters. South of Martha's Vineyard, U. S. F. C. Station 2183, in 195 fathoms, 1884. Page 235.

Fig. 9. *Yoldia callista* Bush. Interior view; × 12 diameters. Page 233.

Fig. 10. The same. Exterior view; × 12 diameters.

Fig. 11. *Skenea lirata* Verrill (*Adeorbis supranitidus* Wood, var. *Orbignyi* Fischer, t. Dall). Front view; × 12 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2278, in 16 fathoms, 1884. Page 240.

Fig. 12. The same. View of base; × 12 diameters.

Fig. 13. *Astyris pura* Verrill. Front view; × 6 diameters. South of Martha's Vineyard, U. S. F. C. Station 894, in 365 fathoms, 1880. Page 240.

Fig. 14. *Trophon abyssorum* Verrill. Front view; × 3 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2115, in 843 fathoms, 1883. Page 240.

Fig. 15. *Trophon abyssorum*, var. *limicola* Verrill. Front view; × 3 diameters. South of Martha's Vineyard, U. S. F. C. Station 2084, in 1,290 fathoms, 1883. Page 240.

Fig. 16. *Trophon Verrillii* Bush. Front view; × about 2 diameters. Page 214.

Fig. 17. *Scala leptalea* Bush. Front view; × 3 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2277, in 16 fathoms, 1884. Page 240.

Fig. 18. *Marginella Smithii* Verrill (*Marginella aureocincta* Stearns, t. Dall). Front view; × 9 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2272, in 15 fathoms. Page 240.

Fig. 19. *Cingula Sandersoni* Verrill. Front view; × 9 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2109, in 142 fathoms, 1883. Page 240.

Figures 2, 9, and 10 were drawn by Mr. J. H. Emerton; Figures 3 to 5*a* and 16, by Mr. W. F. Hopson; and the others, by Mr. J. H. Blake.

PLATE II.

Fig. 1. *Sipho cælatulus* Verrill and Smith. Front view; × 3 diameters. East of George's Bank, U. S. F. C. Station 2077, in 1,255 fathoms, 1883. Page 213.

Fig. 2. *Pleurotomella* (?) *Dalli* Bush. Front view; × 4 diameters. Page 208.

Fig. 2*a*. The same. Apical whorls; × 8 diameters.

Fig. 3. *Pleurotomella atypha* Bush. Front view; × 2 diameters. Page 205.

Fig. 4. *Pleurotomella sulcifera* Bush. Front view; × 2 diameters. Page 207.

Fig. 5. *Pleurotomella leptalea* Bush. Front view; × 3 diameters. Page 208.

Fig. 5*a*. The same. Apical whorls; × 8 diameters.

Fig. 6. *Cocculina reticulata* Verrill. Side view; × 8 diameters. Off Chesapeake Bay, U. S. F. C. Station 2265, in 70 fathoms, 1884. Page 240.

Fig. 6*a*. The same. A section to show style of sculpture; greatly enlarged.

Fig. 7. The same. Interior view, with the animal; × 8 diameters.

Fig. 8. *Diaphana Lottæ* Bush. Top view; × 3 diameters. Page 222.

Fig. 9. The same. Front view; × 3 diameters.

Fig. 10. *Margarita* (*Solariella*) *infundibulum* Watson, var. *Diomedeæ* Verrill. Front view; about natural size. South of Martha's Vineyard, U. S. F. C. Station 2221, in 1,525 fathoms, 1884. Page 218.

Fig. 11. The same. View of base; about natural size.

Fig. 12. *Periploma abyssorum* Verrill. Type specimen. Interior view; about natural size. East of Banquereau, U. S. F. C. Station 2484, in 204 fathoms, 1885. Page 227.

Fig. 13. The same. Exterior view; about natural size.

Fig. 14. *Pandora Carolinensis* Bush. Interior view of inferior valve; × 2 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2113, in 15 fathoms, 1883. Page 240.

Fig. 15. The same. Interior view of superior valve; × 2 diameters.

Fig. 16. *Lucina Blakeana* Bush. Dorsal view; natural size. Page 231.

Fig. 17. The same. Exterior view; natural size.

Fig. 18. *Myonera paucistriata* Dall. Exterior view; × 3 diameters. Page 227.

Fig. 19. *Limopsis plana* Verrill. Type specimen. Interior view; × 2 diameters. Off Chesapeake Bay, U. S. F. C. Station 2098, in 2,221 fathoms, 1883.

Fig. 20. The same. Exterior view; × 2 diameters. Page 240.

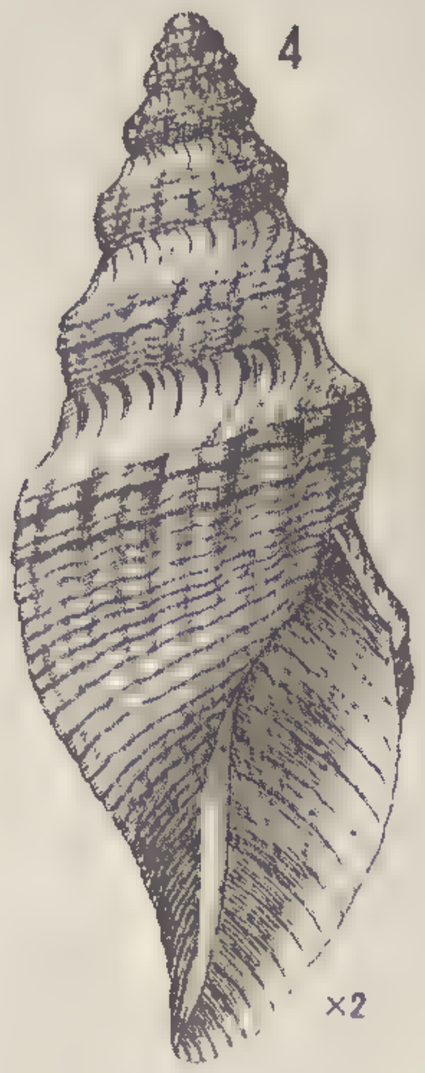
Figures 2, 2*a*, 3, 5, 5*a*, 8, 9, and 16–18 were drawn by Mr. J. H. Emerton; Figure 4, by Mr. W. F. Hopson; and the others, by Mr. J. H. Blake.

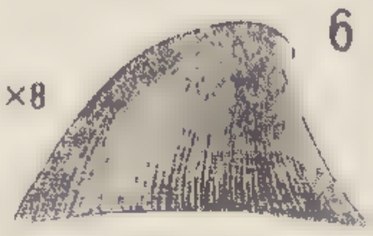
1
×3

2a
×8

2
×4

3
×2

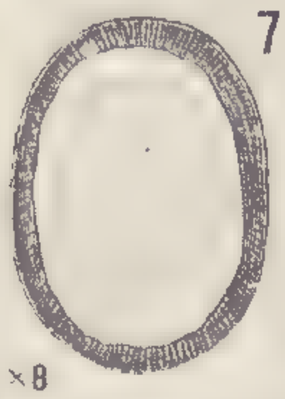

4
×2


6
×8

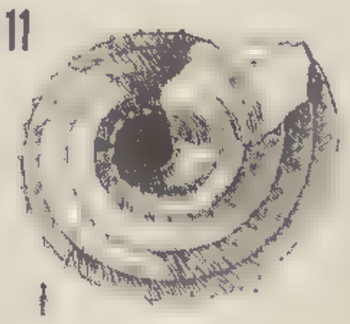
6a

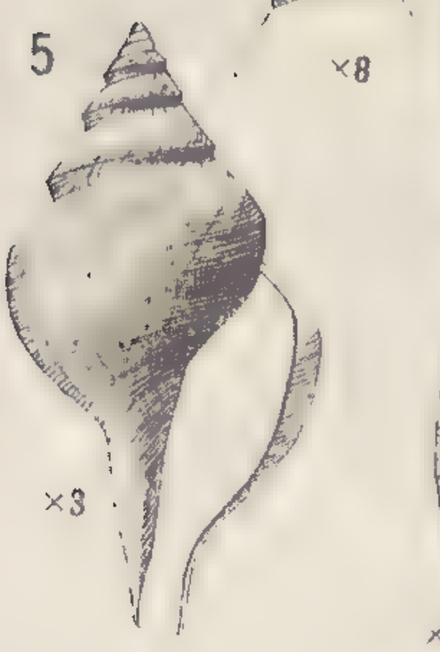
5a
×8

8
×3


7
×8

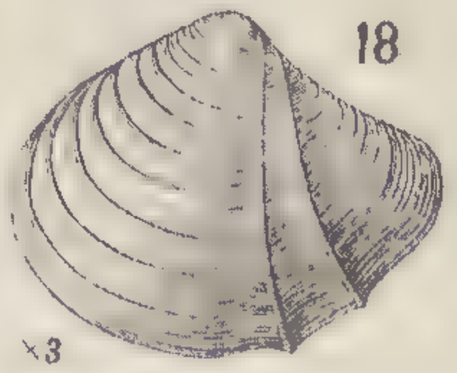
10
1


11
1


5
×3

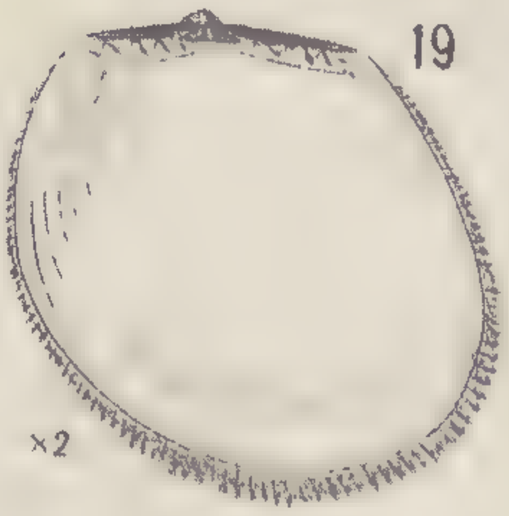
9
×3

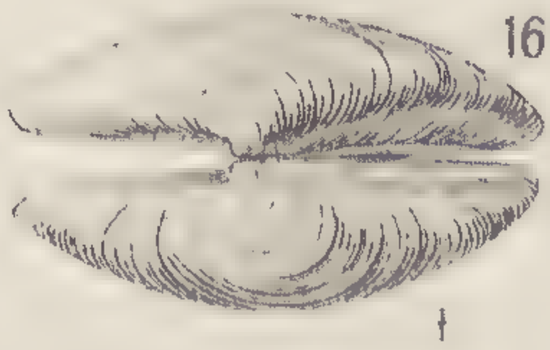
14
×2

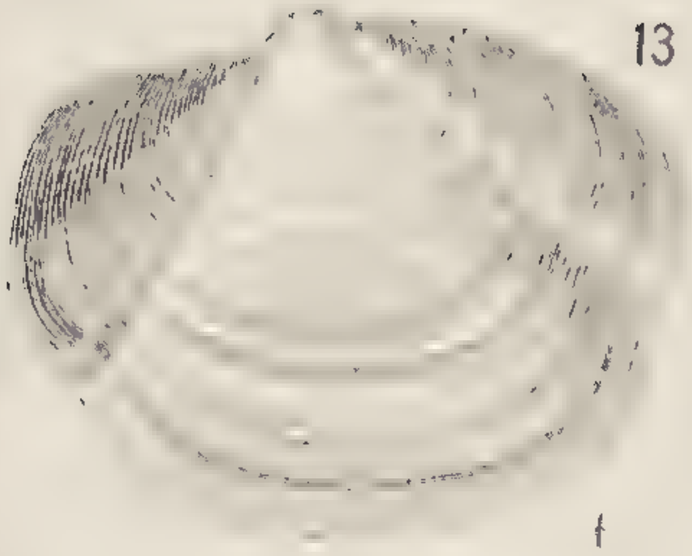

18
×3

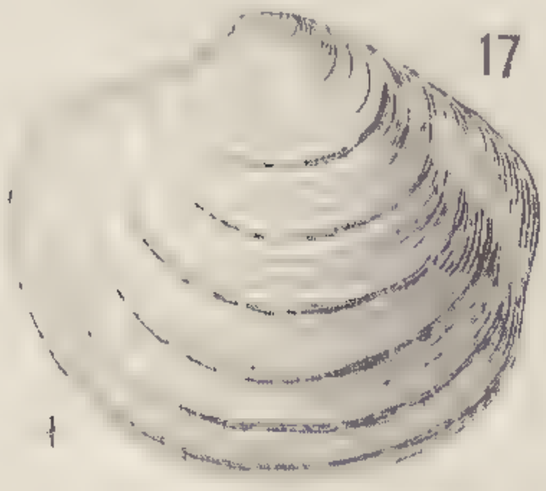
12
1

15
×2


19
×2


16
1


13
1


17
1

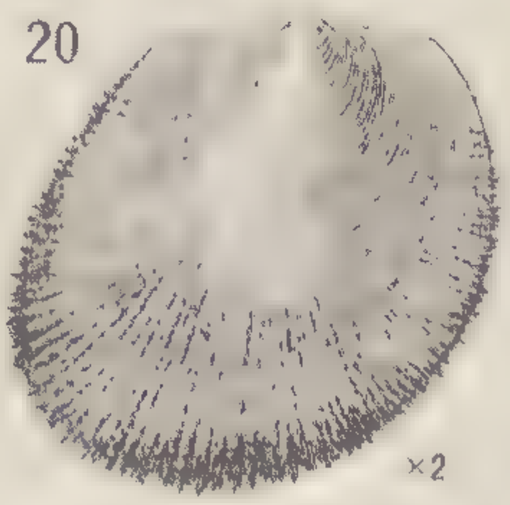

20
×2

Photo. Lith. by L. S. Punderson, New Haven.